FINAL DRAFT

Adaptive Protocols for Lake Okeechobee Operations

Ecosystem Restoration, Water Supply, and Operations Control and Maintenance Engineering Departments, South Florida Water Management District

Developed in Cooperation with:

United States Army Corps of Engineers, Jacksonville District

and

Florida Department of Environmental Protection

ACKNOWLEDGEMENTS

The Adaptive Protocols for Lake Okeechobee Operations were developed to provide guidance in operations for protection of Lake Okeechobee and downstream ecosystems while providing a reliable water supply for agricultural and urban areas that depend on the Lake. This document was developed as a cooperative effort by staff in the Ecosystem Restoration, Water Supply, and Operations Control and Maintenance Engineering Departments of the South Florida Water Management District, and staff at the Jacksonville District of the United States Army Corps of Engineers and the Florida Department of Environmental Protection.

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TABLE OF CONTENTS

Acknowledgements	2
List of Acronyms Used in the Document	4
Executive Summary	5
Introduction and Purpose of this Document	6
Legal Framework of this Document	8
Background of this Document	10
Adaptive Assessment	12
Specific Procedure for Environmental Water Deliveries	16
Application of Regional Performance Measures	17
Lake Okeechobee Performance Measures	17
Estuary Performance Measures	23
Water Supply Performance Measures	27
Everglades Performance Measures	47
STA Performance Measures	55
Regional Simulation Modeling	57
References	64
Appendix I – Information Regarding the Palmer Drought Index	74
Appendix II – Restoration Targets and Minimum Flows and Levels in the Everglades Protection Area	75

LIST OF ACRONYMS USED IN THE DOCUMENT

AWC = available water content
CE = Caloosahatchee Estuary
CERP = Comprehensive Everglades Restoration Program
C&SF = Central and Southern Florida (flood control project)
CPC = Climate Prediction Center
EAA = Everglades Agricultural Area
ECP = Everglades Construction Project
ENP = Everglades National Park
EPA = Everglades Protection Area
FDEP = Florida Department of Environmental Protection
FFWCC = Florida Fish and Wildlife Conservation Commission
HSM = Hydrologic Systems Modeling Division
LEC = Lower East Coast
LECRWSP = Lower East Coast Regional Water Supply Plan
LNWR = Loxahatchee National Wildlife Refuge
LONISF, LONIMSF = Lake Okeechobee Net Inflow Seasonal (and Multi-Seasonal) Forecasts
LOSA = Lake Okeechobee Service Area
MFL = Minimum Flow and Level
NGVD = National Geodetic Vertical Datum of 1929 (formerly called "mean sea level")
NSM = Natural Systems Model
P = phosphorus
PA = Position Analysis (modeling procedure)
PDSI = Palmer Drought Severity Index
SA-1, SA-2, SA-3 = Service Areas 1, 2 and 3
SAV = submerged aquatic vegetation
SFWMD = South Florida Water Management District
SFWMM = South Florida Water Management Model
SLE = St. Lucie Estuary
STA = Stormwater Treatment Area
TC = tributary conditions
RECOVER = Restoration Coordination and Verification (a CERP program)
USACE = United States Army Corps of Engineers
USEPA = United States Environmental Protection Agency
VEC = Valued Ecosystem Component (key biota in the estuaries)
WCA = Water Conservation Area
WRAC = Water Resources Advisory Commission
WSE = Water Supply and Environment (current lake regulation schedule)

EXECUTIVE SUMMARY

Adaptive Protocols for Lake Okeechobee Operations

Lake Okeechobee is the heart of the Central and Southern Florida Flood Control Project and an interconnected regional aquatic ecosystem. It has multiple functions, including flood control, agricultural and urban water supply, navigation, recreation, and fish & wildlife enhancement. As such, operation of the Lake impacts a wide range of environmental and economic issues. Lake operations must carefully consider the entire and sometimes conflicting needs of the Project. A new regulation schedule for Lake Okeechobee, called WSE (Water Supply and Environment), was adopted by the United States Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD) in July 2000. The schedule provides increased flexibility relative to earlier flood control schedules, and was specifically designed to "*optimize environmental benefits at minimal or no impact to competing lake purposes*."

The lake regulation schedule tells water managers when it is necessary to release water from the Lake for project purposes (e.g., flood protection). Release decisions are determined by elevation of the Lake surface, which varies with season, and by recent rainfall amounts and future climate projections. Except at extreme high water level, the regulation schedule does not specify exact discharges. It also does not address situations where water deliveries from Lake Okeechobee may be needed to deal with water resource problems (e.g., high salinity that is affecting submerged plants) in downstream systems, such as the Caloosahatchee River and Estuary. However, the Water Control Plan for the Lake does authorize release of water from the Lake independent of regulatory releases, for water supply for fish and wildlife and for saltwater management.

This document spells out in greater detail how water managers can meet the intent of the WSE lake regulation schedule and the Water Control Plan provisions. In particular, it is a tool to guide operational actions regarding volumes of water to release from the Lake for regulatory purposes and procedures to be followed for addressing downstream water resource opportunities. This document lays out a process that includes input from the public, other agencies, the SFWMD Governing Board, and technical input from experts at the USACE, SFWMD, and Florida Department of Environmental Protection (FDEP). Technical information regarding the need for water releases from the Lake is based on a set of quantitative performance measures of ecosystem health and water supply conditions that have a strong foundation in regional environmental science and engineering.

A key feature of Adaptive Protocols is balancing water supply, flood protection, and environmental protection within the constraints of the approved lake regulation schedule and Water Control Plan. Adaptive Protocols will be a continual adaptation process, in the sense that they will be adjusted, as necessary, to deal with unforeseen issues not accounted for in this document.

1. Introduction and Purpose of this Document

Lake Okeechobee is the heart of the Central and Southern Florida (C&SF) Flood Control Project and of an interconnected regional aquatic ecosystem, and as such, its operation affects a range of environmental and economic issues. Operations of the lake accommodate numerous, and sometimes conflicting, project purposes. A key feature of Adaptive Protocols is balancing water supply, flood protection, and environmental protection.

A new regulation schedule for the Lake was formally adopted in July 2000 by the South Florida Water Management District (SFWMD) and the United States Army Corps of Engineers (USACE). The schedule, referred to as WSE (Water Supply and Environment), provides increased operational flexibility relative to earlier schedules. The WSE schedule has multiple operational zones (**Figure 1**) in which discharges at higher lake stages (Zone D and above) are determined based on meteorological forecasts, climate outlooks, effects to ecosystems, and review of regional hydrologic conditions. Technical information is provided by an interdisciplinary group of scientists, engineers, and resource managers, and release decisions are made by the USACE, following guidelines established by the WSE regulation schedule (USACE 1999). At lower lake stages (below Zone D) there are minimum flows and levels criteria for protection from significant harm to the water resources. There also is a region of Supply Side Management, where water deliveries from the lake for consumptive use may be constrained by criteria set forth in the Lake Okeechobee Supply Side Management Plan (SFWMD 1991), as modified in the Lower East Coast Regional Water Supply Plan (LECRWSP) (SFWMD 2000a).

The purpose of this document, Adaptive Protocols for Lake Okeechobee Operations, is to describe a process for implementing those opportunities for operational flexibility that exist in the WSE Schedule, as well as provisions of the Water Control Plan that address non-regulatory releases of water for fish and wildlife protection and salt water management. The document explains in detail how multidisciplinary technical information will be used in support of Lake operations under the WSE schedule, and how the SFWMD may request that the USACE carry out water deliveries from the Lake to protect downstream natural resources. The overall purpose of Adaptive Protocols is to provide information to system operators for greater protection of Lake Okeechobee and downstream ecosystems, while continuing to provide a reliable supply of water for agricultural and urban areas that depend on the Lake.

It is important to recognize the constraints that presently are placed on Lake Okeechobee when considering the magnitude of benefits to be expected from the Adaptive Protocols. Until the completion of CERP projects that provide large-scale alternative water storage locations in south Florida, the Lake itself must continue to provide a reliable supply of water. In addition, the structural configuration of the C&SF system limits the extent to which water can be discharged out of the Lake during periods of high inflow, without causing damage to downstream ecosystems. Because the C&SF system is a Federal project, water discharges through USACE operated structures (e.g., S-77, S-308) ultimately are the decision of that agency, and as such, are subject to additional constraints. These include USACE operational authorizations, such as the navigation mission, and periodic constraints such as scheduled and emergency structure maintenance. Adaptive Protocols are not solutions to the problems facing the Lake or other natural areas in south Florida. Rather, they represent a flexible process for optimizing how the Lake is operated within the constraints of existing authorizations, using a process that gives careful consideration to various competing uses of the water resource.

Adaptive protocols are implemented in two ways:

(a) where the WSE schedule indicates that water must be released from the Lake for flood control purposes, but does not indicate the exact amount of water to be discharged (in the decision tree, these releases only are specified as "up to" some maximal amount); and

(b) where the Water Control Plan authorizes releases of water from the Lake for water supply, fish and wildlife protection, and salt water management in downstream water resources.

WSE Releases

When the lake regulation schedule requires that water must be released from the lake to the estuaries and/or Water Conservation Areas (WCAs), SFWMD experts on estuarine, lake, and wetland ecology will provide scientific input with regard to the effects of various discharge volumes. Technical experts on agricultural and urban water supply will provide similar input regarding the anticipated effects on that use of the water resource. In general, when flood protection releases are required by the WSE schedule, risks to agricultural or urban water supply are low, because that issue has been accounted for within the schedule's two decision trees that can be viewed at: http://www.saj.usace.army.mil/h2o//lib/documents/WSE/index.html. The fact that a flood protection release is required indicates that the lake is high and/or conditions in upstream tributaries are wet and heavy rainfall is projected in the watershed. Likewise, when releases are required by the WSE schedule, it is implicit that the Lake's littoral zone will benefit from those water releases, which will reduce Lake water level and thereby minimize ecological stress. Consequently, impacts to downstream ecosystems, including the east and west coast estuaries and WCAs, are major considerations. Those impacts will be evaluated on the basis of existing conditions in the ecosystems, as quantified by the performance measures described in Section 5 of this document. Consideration also will be given to opportunities to minimize impacts in the longer term. The latter is important because past experience shows that low-volume discharges carried out in a pro-active manner can reduce the later need for more damaging high-volume discharges and also reduce littoral zone impacts due to rapidly rising stages. This array of technical information will form the basis for SFWMD input regarding the specific volume and duration of flood control releases under the WSE schedule, actions that are the responsibility of the USACE.

Environmental Water Deliveries

There may be circumstances where the regulation schedule does not indicate that water should be released from Lake Okeechobee for flood protection, but water deliveries from the Lake are needed to protect downstream ecosystems. These releases are authorized by the Water Control Plan (Sections 7-08 to 7-10) and by Florida Statutes (Chapter 373, F.S.). For example, freshwater deliveries from the Lake may be required to reduce salinity in the Caloosahatchee River or flush out an algal bloom in that same system. SFWMD staff will approach such releases in a pro-active manner by vetting the supporting information at a regularly scheduled Governing Board meeting, prior to carrying out the actual operation. Information presented to the Board will include expected benefits and potential risks of the operation, and the specific duration and magnitude of flow that are anticipated to occur. If environmental water delivery actually is needed during the subsequent month, the SFWMD will request that the USACE carry out the operation for the specified period of time and at the specified rate of flow. Downstream and in-lake responses to the lake water release will be carefully monitored, as well as changes in climate or hydrologic conditions that might influence benefits or potential risks. The Governing Board will be briefed regarding the results of the operation at their next regularly scheduled meeting. They will also be apprised of the facts related to potential additional releases of water. The overall process for making environmental water deliveries is designed to protect the ecosystem, but also minimize the risk of having permitted users experience water use restrictions (SFWMD 1991, 2000b).

The Water Resources Advisory Commission (WRAC) provided the following recommendations in regard to environmental water deliveries from Lake Okeechobee --

(a) *The Adaptive Protocols should include the option of making environmental water deliveries to the Caloosahatchee River or other downstream water resources, but with a 10-day average discharge volume not exceeding 300 cfs, unless specifically authorized by the Governing Board of the SFWMD.*

(b) *Environmental water deliveries, as specified in item (a), should occur only when the Lake is in Zone D or above in the WSE Regulation Schedule. Otherwise, they should only occur with specific approval by the Governing Board of the SFWMD.*

(c) *The SFWMD should take advantage of opportunities where the WSE schedule calls for discharges to the WCAs to provide freshwater to meet up to 300 cfs demands of the Caloosahatchee ecosystem, as long as that water is not required by the WCAs.*

2. Legal Framework of this Document

Lake Okeechobee structures within the C&SF Project are operated pursuant to the Water Control Plan for Lake Okeechobee and the Everglades Agricultural Area, which is a federal regulation. The Water Control Plan contains the Lake Okeechobee Regulation Schedule, which at the present time, is the WSE Schedule. As the local sponsor of the

C&SF Project, the District is subject to, and bound by, federal regulations, such as the Water Control Plan.

The Water Control Plan provides for regulatory releases (s. 7-03, WCP), water supply releases for estuarine, Everglades National Park, agriculture, urban and fish and wildlife purposes (S. 7-10, WCP); fish and wildlife preservation and enhancement (S. 7-09, WCP); and water quality protection (S. 7-08, WCP). Some specific considerations mentioned in the Water Control Plan are ecological status of the Lake's littoral zone and estuaries, climate outlooks and projected water use demands. As part of this overall scheme, the lake regulation schedule establishes ranges for regulatory releases for flood control and requires discharges to be identified based on multiple objectives in a decision tree format. The Water Control Plan authorizes non-regulatory releases, such as water supply releases to the estuaries, within any zone. As stated in the Water Control Plan, the District is responsible for allocating water (e.g., issuing consumptive use permits or adopting water reservations) from Lake Okeechobee for water supply purposes.

Independent of the federal regulations, under Chapter 373, F.S., the District has the authority to establish, maintain and regulate water levels in water bodies owned, maintained or controlled by the District and to regulate discharges into, or withdrawals from water bodies through "Works of the District" SS. 373.086, 373.103(4), F.S. This authority is implemented to effectuate the purposes of Chapter 373, including flood control, water supply, environmental protection and water quality protection. See Sections 373.016, 373.036 and 373.1501, F.S. Lake Okeechobee is a "work of the district" pursuant to Chapter 25209, Laws of Florida.

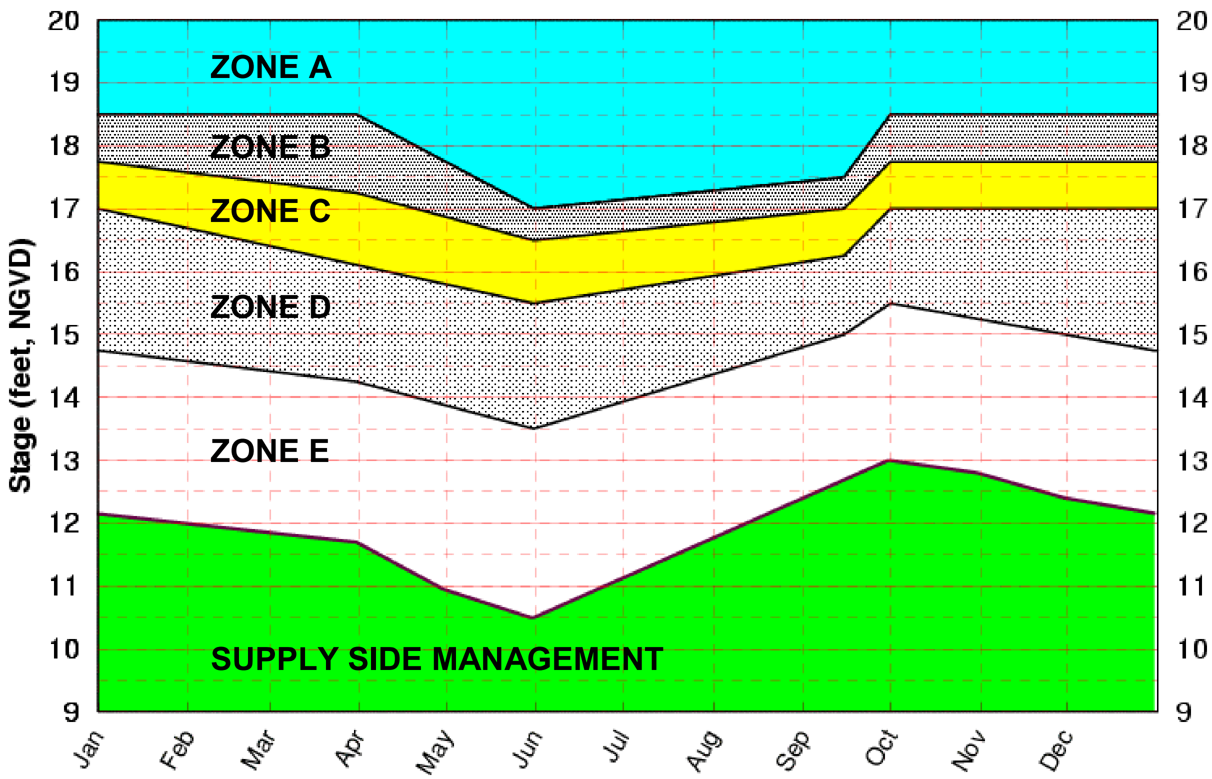
Decisions made for water releases from Lake Okeechobee for environmental water supply or management of water levels for environmental purposes, such as protection of the lake’s littoral zone, must be made consistent with the Water Control Plan and Chapter 373, F.S. Specific guidance on these releases, such as the alternative flow ranges provided for making regulatory releases in the schedule, is not provided in the Water Control Plan. Therefore, pursuant to its authority under Chapter 373, the District has identified procedures and relevant performance measures in this Document to be used in the decision making process for reviewing the need for and viability of these types of releases.

This Document is intended to formalize the process for District input to the USACE for Lake Okeechobee operations under the WCP. It is also intended to establish an internal process for staff to obtain policy direction from the Executive Office and the Governing Board on significant operational policy issues. It applies where ranges or objectives are provided for determining flood control and water supply releases under existing federal and state authority. It is not intended to establish, dictate or regulate water levels or operations. Full discretion of the USACE and the District, as the local sponsor, to operate the C&SF project is retained as provided in the WCP. The document is not self-executing, and does not bind the district or any other person to take, or not to take, any specific action.

3. Background of this Document

The Adaptive Protocols for Lake Okeechobee Operations address an information need identified in the Final Environmental Impact Statement (EIS) of the WSE schedule (USACE 1999, p. 63), where it is indicated that "*Releases through various outlets may be modified to minimize damages or obtain additional benefits. Consultation with Everglades and estuarine biologists is encouraged to minimize adverse effects to downstream ecosystems*." The Adaptive Protocols include the process whereby this flow modification and expert consultation occurs. All of the operations under Adaptive Protocols are consistent with existing authority provided by the Water Control Plan for the Lake.

Figure 1. Management zones for Lake Okeechobee, including Zones A-E associated with the WSE regulation schedule and the Supply Side Management zone.



The WSE schedule makes use of a decision tree that indicates whether or not regulatory releases are required. The range of water released to the estuaries in that decision tree is from "up to maximum discharge" in the case where the Lake is in Zone A of the regulation schedule, and "no discharge to tide" when the Lake is in Zone D and tributary conditions are dry. Other endpoints occur between these extremes. Likewise, the range of water released to the WCAs is from "maximum practicable flow" in Zone A to "no flow" in Zone D with dry conditions. When regulatory releases are required (to the estuaries and/or WCAs), it still is necessary to determine the volumes of discharge to be made to each downstream water body. The schedule only provides information on possible ranges of discharge volumes, not exact amounts. When regulatory releases are not required by the schedule, the SFWMD, under its authority to water supply discharges from the Lake (Chapter 373, F.S.), will consult with the USACE and FDEP, and may request such releases for the purpose of protecting regional water resources.

Under ideal circumstances, water levels in the Lake would not rise into any of the zones where WSE-driven regulatory releases are required, or fall into the region of Supply Side Management. In reality, those conditions do occur because water levels in the Lake are driven by regional rainfall and runoff, rates of evapotranspiration, and amount of water supply demand. Regional restoration projects identified in the Comprehensive Everglades Restoration Program (CERP) include alternative water storage locations that are expected to help attenuate peak flow during periods of high rainfall, and take some pressure off the Lake as a regional water supply source. This should help reduce the occurrence of undesirable high and low water levels, respectively. However, until the CERP is implemented, innovative operational protocols must be applied within the constraints of the existing infrastructure and operational and legal authorities to ensure that water managers can take advantage of certain opportunities to maximize benefits for the water resource and its various uses.

In addition to language in the Final Environmental Impact Statement for the WSE Regulation Schedule (USACE 1999), the LECRWSP (SFWMD 2000a, p. 307-308) explicitly refers to development of flexible operational protocols. That document states that the protocols should: (1) have specific stated goals and objectives; (2) have real-time performance measures that "*include success criteria for all significant environmental components, water shortage implementation, flood control management, and water quality assessment*;" and (3) be flexible, providing the "*capability to pro-actively react to changing climatological outlooks and environmental conditions*." Development of Adaptive Protocols, as part of the larger regional water supply planning effort, is consistent with the policy direction provided in Florida Statutes (Section 373.016). Details regarding this authorization may be found in the LECRWSP (SFWMD 2000a, p. 7). Under certain conditions, Adaptive Protocols also might provide the SFWMD with the opportunity to address recovery and prevention strategies for meeting Minimum Flows and Levels (MFLs) in the Lower East Coast Regional Planning Area. MFLs were adopted in September 2001 for the Caloosahatchee Estuary, Lake Okeechobee, the Everglades Protection Area, the Biscayne Aquifer, and the Lower West Coast Aquifer, and in 2002 for the St. Lucie Estuary. It is recognized, however, that until a number of CERP projects are completed, MFLs for these areas cannot always be met with existing water resources and project infrastructure. Adaptive Protocols will allow the SFWMD to take advantage of periodic opportunities, but are not a MFL recovery plan.

3. Adaptive Assessment

3a. Overview of the Process

Adaptive Protocols for Lake Okeechobee are patterned after the Adaptive Assessment process of the Comprehensive Everglades Restoration Plan's Restoration Coordination and Verification (RECOVER) program. Adaptive Assessment is a process of passive adaptive management, or "learning by doing," which involves active monitoring of system responses to operations, quantifying those responses using a set of resource performance measures, and then making subsequent operational changes with the increased knowledge base that comes from this feedback process. The process of Adaptive Protocols includes: (a) twice-yearly public workshops, at the beginning of the wet and dry seasons, where Lake operations are discussed in a venue that allows for a high degree of input from agencies, tribes, and the general public; (b) quarterly update meetings with the Water Resources Advisory Commission (WRAC); (c) monthly briefings of the SFWMD Governing Board, and (d) real-time operations of the lake, in coordination with the USACE and FDEP. The semi-annual workshops and quarterly meetings with the WRAC will take the place of the "WSE meetings" that have occurred in the past.

3b. Semi-Annual Public Workshops

An important component of the Adaptive Protocols is gathering constructive input from the wide range of agencies and members of the general public concerned with and knowledgeable about the regional water resource. Past experience indicates that the best venue for two-way dialogue between agency staff and stakeholders is an open public workshop that is focused on one particular topic, in this case the management of water levels in Lake Okeechobee. The WRAC provided the following specific recommendation regarding semi-annual workshops:

> *The Adaptive Protocols process should include open public workshops at the start of wet and dry seasons to receive public comments, review regional conditions, examine past operations and their benefits / impacts, and discuss operations for the next six months.*

Following this recommendation, open public workshops will be held at the beginning of each wet and dry season (in May - June and November - December, respectively). These workshops will include presentations by SFWMD and USACE staff on: (a) operations during the past season; (b) environmental and/or water supply benefits achieved; (c) benefits not achieved or impacts documented; (d) present status of the regional system; (e) short and long-term climate outlook, including drought index conditions; and (f) projected stage in the Lake and other regional surface water storage locations based on Position Analysis modeling (see section 5c). On the basis of this information, staff will present to the audience the anticipated operations for the upcoming wet or dry season. Results of the workshop, including a technical summary and overview of public input, will be presented to the Governing Board at their next regularly scheduled meeting. This briefing of the

Board will define the general Lake operating conditions for the next wet or dry season. The overall process is illustrated as a feedback loop in **Figure 2**.

3c. Quarterly Meetings with the WRAC

Meetings with the Water Resources Advisory Commission provide an additional (quarterly) venue for dialogue with other agencies, tribes, and the general public about management of the Lake. The WRAC includes a representative from the SFWMD Governing Board, and representatives from the USACE, other state, federal, and tribal agencies, and major interest groups. WRAC members have a unique understanding of South Florida water resource issues, and as such, can view the Lake Okeechobee situation in a broad-based regional context. As indicated above, the SFWMD Governing Board also will be briefed on the status of Lake operations on a monthly basis, as part of their regularly scheduled meetings. These components of the feedback process are included in **Figure 2**.

3d. Real-Time Lake Operations

On a weekly or more frequent basis (depending on circumstances), technical staff will provide input (**Figure 3**) to system operators, including updates of weather and climate conditions, regional hydrologic conditions, the status of regional water resources, and results from decision trees in the WSE regulation schedule. This technical information is used by the USACE to determine amounts of water to release from the lake under the WSE schedule. Water deliveries for protection of downstream ecosystems, made under the SFWMD authority to provide water supply, will be consistent with the operations described at the prior briefing of the SFWMD Governing Board, and also will follow the specific process described in Section 4 of this document.

3e. Regional System Monitoring and Performance Measures

Central to the adaptive protocol process are a set of ecosystem and water supply performance measures (quantifiable measures of success with defined targets), and a regional monitoring program that provides the information necessary to derive performance measure scores. This monitoring includes a variety of system attributes (listed in more detail below) including estuary salinity ranges, lake water levels, key biological indicators, as well as regional water supply needs. The individual performance measures and the monitoring necessary to quantify their status and trends are described in detail, along with their technical foundation, in subsequent sections of this document. Performance measures are used both to assist in real-time operations of the Lake, and to provide a summary of system performance at the public workshops and the WRAC and Governing Board briefings.

Figure 2. Generalized feedback loop for public input regarding the operations of Lake Okeechobee in the Adaptive Protocols process.

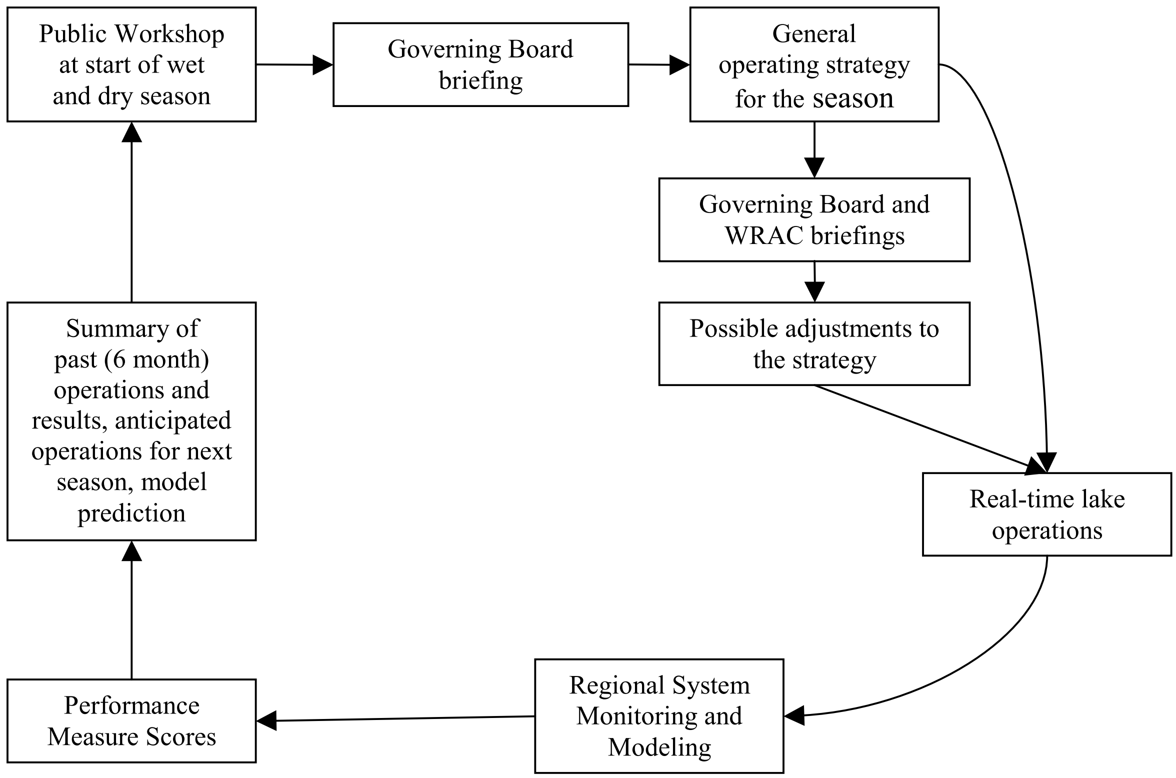
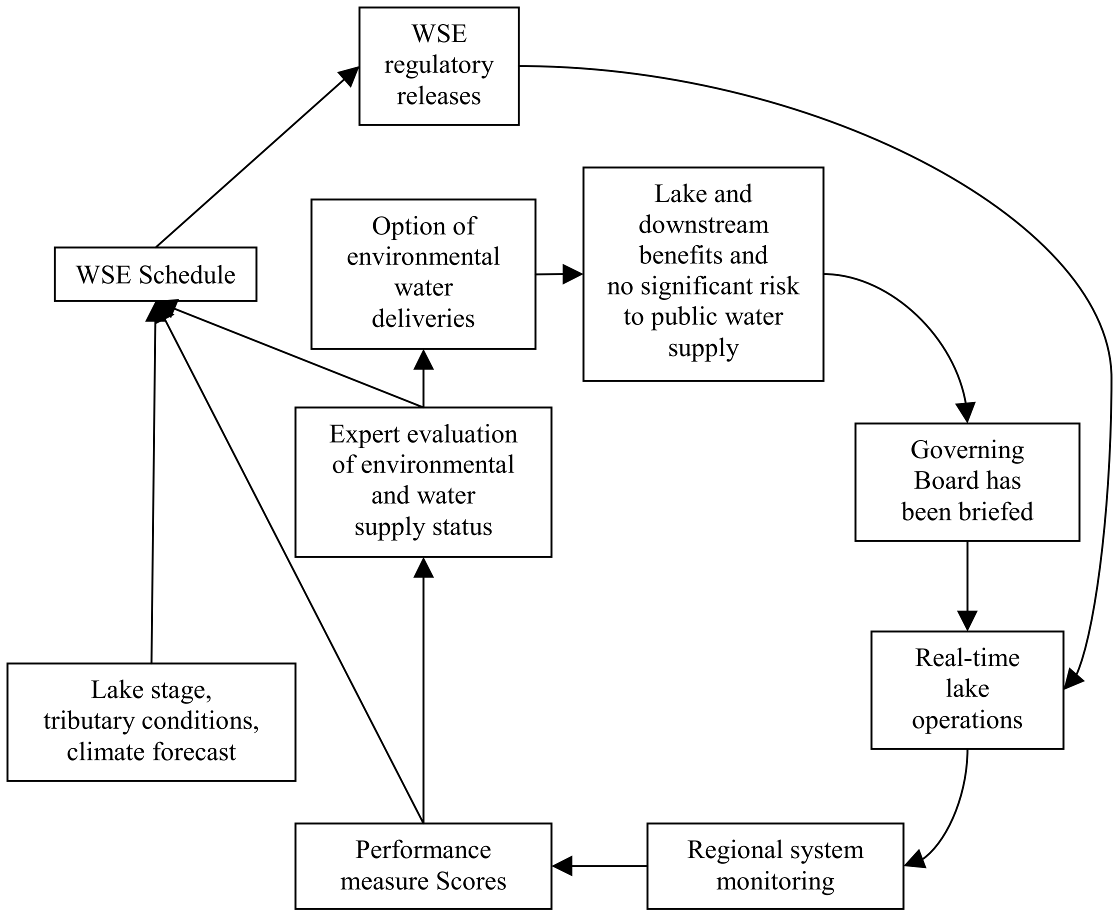


Figure 3. Feedback loop for real-time operations of the Lake, indicating how results of the WSE schedule are meshed with the regional performance measure monitoring to determine flood control releases (under WSE), environmental water needs, and water supply effects. In cases where flood control releases are not required by the WSE

schedule, deliveries to downstream water resources can be made as long as there is anticipated to be minimal or no impact to agricultural and urban water supply, based on performance measures described in Section 5e of this document. Real-time operations will be consistent with the general strategies established following semi-annual public workshops and monthly Governing Board briefings.



4. Specific Procedure for Environmental Water Deliveries

Adaptive Protocols are designed to identify potential "win-win" situations in which one or more environmental resources can benefit from a Lake release and where there is anticipated to be minimal or no adverse effect on meeting future agricultural or urban water supply needs. The process carefully examines potential benefits and risks to the Lake in regard to its ecological integrity and the established Lake MFL criteria. When all pertinent facts indicate that a water delivery to a downstream resource is likely to be required in the upcoming month, the Governing Board will be briefed at their next regularly scheduled meeting. If conditions develop as expected and the environmental water delivery becomes necessary, a request will be made to the USACE to discharge water from their structures at the volume and duration that does not exceed what was indicated at the Governing Board briefing. Prior to the environmental water delivery, there will be a posting of information on the Lake Operations web site of the SFWMD [www.sfwmd.gov] to notify affected interests of the operation.

During an environmental water delivery, the following additional procedures will apply. The overarching principle is that the SFWMD Governing Board has been briefed on the operation, and that the environmental water deliveries are supported by the USACE and FDEP. When the Lake is below Zone D of the WSE Regulation Schedule, or when environmental deliveries are required in excess of 300 cfs (10-day average), the SFWMD input to the USCAE on whether to make the environmental deliveries will be based on specific Governing Board discussion and direction.

(a) Regular meetings will be held by the directors of Water Supply, Ecosystem Restoration, and Operations Control, along with a representative of Office of Counsel, to discuss status of the ongoing operation. Consideration will be given to changes based on both environmental responses and water supply implications.

(b) During the operations, technical staff will consult on a regular basis with the USACE and FDEP, discuss status of the operation and observed system responses, and indicate whether or not there is a need for any change in the water delivery. Changes might include increased or decreased discharge volume or duration, within the constraints established at the prior Governing Board briefing.

(c) Monitoring and assessment will occur to document water delivery effects on downstream ecosystem(s), changes in the Lake, and any changes in water supply risk to ensure a sound technical basis for the discussions stated in (a) and (b) above.

(d) In addition to posting updates on the Lake Operations web site regarding the status of the operation, there will be periodic press releases to notify the public of the operation status and its documented benefits.

(e) SFWMD staff will document the operation on the web site, including its duration, benefits to the environmental resources, and any effects, or lack thereof, on the Lake and regional water supply.

5. Application of Regional Performance Measures

For each distinct environmental region of the system (Lake Okeechobee, Caloosahatchee Estuary, St. Lucie Estuary, and Water Conservation Areas of the Everglades Protection Area), a set of hydrologic and biological performance measures will be used in the Adaptive Protocols process to identify the need for water releases from the Lake. Water supply performance measures also will be used to identify the level of risk to that use of the Lake resource. Hydrologic and water supply performance measures are patterned after those developed in the LECWSP and the WSE regulation schedule review. Actions to release water from the Lake for protection of natural resources will be based on the regional performance measures. The ultimate goal is to use operational flexibility to facilitate benefits to the environment without impacting other uses of the Lake.

5a. Lake Okeechobee Performance Measures

5a.1 Hydrologic Performance Measures

Hydrologic performance measures for the Lake are documented in the LECRWSP and the Lake Okeechobee Conceptual Ecosystem Model (Havens 2000) for the Restoration Coordination and Verification (RECOVER) program of CERP. They are based on over a decade of rigorous science and peer-reviewed literature (e.g., Maceina 1993, Aumen and Gray 1995, Havens 1997, Havens et al. 1999). The following paragraphs describe the scientific basis of performance measures and the approach for using them as part of the Adaptive Protocols. Along with the hydrologic performance measures, assessment of the Lake's biological status will be based on a comprehensive set of measures, including submerged aquatic vegetation, emergent wetland plants, benthic algae, water clarity, nutrient concentrations, and algal blooms. This information will be the basis for technical input to operators regarding expected Lake responses to water discharges.

There are a total of four hydrologic performance measures for Lake Okeechobee. Three identify adverse impacts from extreme high and low water, and one identifies a optimal annual minimum water level target of approximately 13.5 ft NGVD (National Geodetic Vertical Datum of 1929, formerly called mean sea level) in spring, which has documented ecosystem benefits.

<u>Extreme High Stage</u>

A Lake stage of 17 ft NGVD can adversely effect the Lake's littoral zone, even when it is of short duration. During the late 1990s, the Lake stage exceeded 17 ft NGVD on a number of occasions. The high water levels facilitated the movement of wind-driven waves into the western shoreline, resulting in the erosion of several hundred meters of the western littoral zone where it is in contact with the open water of the lake (Hanlon and Brady 2001). Large areas of bulrush and other plants were torn from the lake bottom and piled on the shoreline, forming a "berm" of dead plant material and fine organic matter (Havens et al. 2001a). This berm acted as a local source of turbidity, preventing light from reaching the adjacent lake bottom, even when stages dropped to 13 ft NGVD. As a result, the shoreline area was devoid of submerged plants; these plants are a critical habitat for fish populations (Furse and Fox 1994). Submerged plants did not re-colonize the area near the berm until the Lake stage fell to near 12 ft NGVD (Havens et al. 2001a). When the Lake stage is at 17 ft NGVD or more there also is evidence that nutrient-rich water from the open-water zone (TP > 100 ppb) is transported into the interior littoral marsh, which normally is pristine and nutrient poor (TP < 10 ppb). This has been documented to cause ecological changes, including altered periphyton structure and function (Havens et al. 1999) and possibly an expansion of cattail. When littoral plants and periphyton change, higher trophic levels also may be affected in the littoral food web of Lake Okeechobee (Havens et al. 2001b, c).

Prolonged Moderate High Stage

Prolonged, moderately high (>15 ft NGVD) stages also result in undesirable biological and water quality impacts in the Lake. The WSE regulation schedule was developed, in part, with this concept in mind. This is reflected by the fact that the base of the regulatory discharge zone (bottom of Zone D) rises above 15 ft NGVD for just a short period of time, peaking at just 15.5 ft NGVD.

The mechanism of impact when the stage is above 15 ft NGVD for many months relates to the depth of the water and increased turbidity. With deeper water, reduced amounts of light reach the lake bottom, resulting in a reduction of submerged plant growth along the shoreline. This phenomenon is well documented in Florida lakes (Canfield et al. 1985), and by cause-and-effect experiments dealing with *Vallisneria* (eelgrass) from Lake Okeechobee (Grimshaw et al. 2002). In addition, when stage in Lake Okeechobee is above 15 ft NGVD, there is transport of re-suspended mud sediment particles from mid-lake to near-shore areas that support submerged plant communities (Maceina 1993, Havens and James 1999, Havens 2002). The consequence is that submerged plants progressively decline under prolonged high-stage conditions due to light limitation. In the late 1990s, after several successive years of high stage, submerged plant coverage in Lake Okeechobee was very sparse, and there were dramatic declines in the Lake's sport fish populations (Florida Fish and Wildlife Conservation Commission [FFWCC], public presentations in 1999 and 2000). When more favorable conditions occurred in summer 2000 (stage near 12 ft NGVD after a managed recession), submerged plant coverage increased from 5,000 to over 40,000 acres (Havens et al. 2001a). This is similar to the coverage documented during the late 1980s and early 1990s, after a period of similar low stage (Richardson and Harris 1995). In addition to biological impacts, stage above 15 ft NGVD (yearly average) also is linked with higher concentrations of phosphorus (Canfield and Hoyer 1988, Havens 1997). This may be due to increased phosphorus transport from mid-lake to near-shore areas (Maceina 1993, Havens 1997) and/or loss of phosphorus assimilation by plants and attached algae (Phlips et al. 1993). Submerged plant beds and algae are a tremendous sink for phosphorus in shallow lakes, often preventing algal blooms from occurring even when high external loading of phosphorus occurs (Scheffer et al. 1994, Havens and Schelske 2001, Havens et al. 2001d). As indicated previously, they also are key areas for fish nesting and foraging activities.

Extreme Low Stage

Effects of extreme low stage (<11 ft NGVD) are documented in the SFWMD (2000c) Minimum Flows and Levels document, and therefore, only a brief summary is provided here. When water levels in the Lake are approaching such an extreme low, there will have been concerns about water supply, estuarine ecology, and saltwater intrusion in coastal areas, as well as recreation and navigation in the Lake and adjacent waterways, which impact the local and regional economy. These concerns could restrict water discharges from the Lake for downstream natural resource protection. If an extreme low stage persists for several months, it can threaten the littoral zone of the Lake by drying out marsh habitat so that it cannot be used by fish, wading birds, migratory waterfowl, the federally endangered Snail Kite, alligators, or other animals (Havens 2002). Extreme low stage also dries out pristine interior littoral areas such as Moonshine Bay, allowing them to be taken over by exotic plants such as *Melaleuca* and torpedograss, which invade more rapidly when soils are not flooded (Lockhart 1995, Smith et al. 2001). An important aspect of extreme low stage is that its impacts depend on return frequency. As long as an extreme low stage does not occur more often than once every 6-7 years, it can provide some benefits to the littoral community. For example, it can favor fires that burn accumulated cattail thatch, and allow buried seeds of native marsh plants to germinate.

Spring Water Level (June)

Research on the Lake's submerged aquatic vegetation community indicates that late spring (early June) water levels near 13.5 ft NGVD could support a healthier and more widespread community than what has occurred in the Lake under higher stage conditions (Havens et al. 2001a, Grimshaw et al. 2002). A healthier submerged vegetation community, in turn, would provide a wide range of benefits to the Lake's fishery, wading bird community, and near-shore water quality and clarity. The submerged vegetation, as noted previously, is considered a keystone component of the Lake community. Lake stage falling from a maximum of near 15.5 ft NGVD in fall-winter to below 13.5 ft NGVD in June would provide other benefits to the ecosystem. It would concentrate prey resources at a time when wading birds and other predators are establishing nests in the littoral zone and raising their young. This could provide a food base to support healthy populations. Likewise, the receding water would allow birds, apple snails, and other animals to construct nests or lay eggs on emergent plants at locations above the water that minimize risks from predators and flooding. One important consequence of this, however, is that if water levels reverse by >0.5 ft / month during a period of decline, damage can potentially occur to these nests and eggs.

Two aspects of spring water level are evaluated with performance measures: (1) the actual stage of the Lake relative to the optimal 15.5 to 13.5 ft NGVD decline from January to June, and (2) the presence of stage reversals during this period of time.

5a.2 Lake Okeechobee Biological Performance Measures

In addition to monitoring and assessing hydrologic conditions in the Lake, the SFWMD monitors key biological indicators of ecosystem health. For Adaptive Protocols, the focus will be on two keystone communities of the lake that are known to be highly responsive to changes in water level – the submerged aquatic vegetation and near-shore bulrush. These communities provide critical habitat for fish and wildlife, they stabilize lake sediments, and the plants and their associated periphyton (attached algae) remove nutrients from the water, directly benefiting water quality. They both are being measured in existing monitoring programs carried out by the SFWMD. Although there presently are not similar programs to evaluate the status of the lake's animal communities, these are expected to become available in the near future, as part of the monitoring program in support of the Comprehensive Everglades Restoration Plan (CERP). When that occurs, there also will be regular monitoring data on the lake for wading birds and forage fish, and possibly benthic invertebrates and open-water fish communities.

Submerged vegetation is monitored at three different spatial and temporal scales by the SFWMD, in a program that started in 1998. First, sampling is conducted on a monthly basis to obtain semi-quantitative data on the status of submerged and emergent plant communities at approximately 10 sentinel stations around the lakeshore. Second, quarterly quantitative sampling is done at stations located along 16 shoreline transects, in order to quantify plant species composition and biomass. Taken together, this information is used to evaluate seasonal changes in the community. It provides information on plant responses to changing water levels on a relatively short time scale, and can be used as input to real-time operations. Third, yearly maps of submerged vegetation are developed by intensive sampling at over 500 locations around the lake shore, near the end of each year's peak growing season (August to September). This provides information on the total number of acres of plants that the lake gained (or lost) under the prevailing hydrologic conditions of a calendar year. This sampling program has indicated that submerged aquatic vegetation can cover more than 40,000 acres when water levels are favorable (e.g., summer 2000 and 2002), as compared to <5,000 acres during periods of prolonged high water level (e.g., 1996 to 1999).

Shoreline bulrush communities also are sampled monthly, in a qualitative survey from boat and/or helicopter, and quarterly quantitative sampling is done at six sentinel stations around the north and west lakeshore. In the quarterly sampling, plant stem densities and heights are recorded, along with water depth and transparency. These programs provide information on plant responses to changing water levels at a relatively short time scale, for input to real-time system management. On a yearly basis, high-resolution aerial photography and Geographic Information Systems (GIS) technology determine the spatial extent of bulrush and other emergent plants along the lakeshore. This provides information on the total number of acres of plants in the lake in any given year. In the early 1990s, when favorable water levels occurred, there was up to 4,700 acres of bulrush. In the late 1990s, as a result of high water level, the acreage was reduced to below 1,000. Bulrush has partly recovered since then, as a result of low water levels in 2000-2001, and a dense community of spikerush also has developed along the lake shore. These communities are providing important fish and wildlife habitat along the northwest shore, in an area where much of the littoral habitat has been degraded due to torpedograss and cattail expansion. Under favorable water levels, the lake should be able to support more than 5,000 acres of shoreline bulrush and spikerush.

A detailed description of sampling methods for submerged and emergent aquatic vegetation in Lake Okeechobee is provided on the SFWMD web site, at the following location: www.sfwmd.gov/lo_statustrends/ecocond/lo_veg.html

5a.3 Performance Measure Integration and Application

Table 1 summarizes the performance measure evaluation scheme that scientists with expertise in the hydrology and biology of Lake Okeechobee will use to evaluate conditions of the ecosystem. A simple color scheme is used, where **red** = high risk of adverse impacts or adverse impacts actually documented, **yellow** = moderate risk of adverse impacts, and **green** = little or no potential for adverse impacts. [Note: if you have a black and white copy of this document, the three color categories appear to be grey, light grey, and dark grey, respectively]. In regard to the performance measure dealing with prolonged moderate high stage, ecosystem impacts depend on whether the condition occurs in winter or summer (when plants and animals are actively growing). Under this scheme, an increasing number of performance measures with black scores indicate a greater risk of damage to the Lake ecosystem. As previously described, this information will be considered in the context of similar performance measure scores from the estuaries, the Everglades Protection Area, and agricultural and urban water supply.

Table 1. Performance measure categories for Lake Okeechobee. Details are provided in the text. In this simple categorization scheme, **red** = high probability of adverse impacts to the ecosystem, yellow = moderate probability of adverse impacts, and **green** = low probability of adverse impacts. An increasing number of performance measures with red categories indicate greater risk to the ecosystem.

Performance Measure		**Categories**
Extreme High Stage	>17 ft	

Impacts can occur rapidly	16 to 17 ft	
Moderate High Stage	Winter	Summer
Stages in excess of 15 ft, impacts build over time	>2 month	
Impacts depend on season	>4 month	
	>6 month	
Extreme Low Stage		
Stages below 11 ft, impacts build over time	>1 month	
Seasonal component not defined	>2 month	
Return frequency (not more often than once every 6 years) also must be considered	>4 month	
Spring Water Level (June)		
Short-term evaluation: deviation of stage above target	<13.5 ft	
	>13.5 ft	
	>14.0 ft	
Short-term evaluation: reversals of stage $\geq$0.5 ft During Jan-June	No	
	Yes	
Biological Conditions	Healthy	
Conditions will be determined for submerged and emergent plant communities. Other community components (e.g., fisheries) will be considered, as information becomes available.	Moderate stress	
	High stress	

5b. Estuary Performance Measures

5b.1 Hydrologic Performance Measures

The St. Lucie Estuary (SLE) and the Caloosahatchee Estuary (CE) are large brackish-water systems on the east and west coast of Florida, respectively, which have the potential to provide vital habitat for substantial populations of fish and invertebrates that have biological and economic importance. The hydrology of both systems has been altered by modification of drainage basins and by artificial connections to Lake Okeechobee. Freshwater input to these systems varies dramatically during a typical year. At times Lake discharge and surface runoff can be of sufficient magnitude to turn these estuaries entirely fresh. At other times, they receive virtually no surface runoff and salinity of the estuaries increases. Annual fluctuations in salinity often exceed the tolerance limits of many estuarine organisms (Haunert and Startzman 1985, Chamberlain and Doering 1998).

The St. Lucie Canal (C-44) and the Caloosahatchee River Canal (C-43) connect these estuaries to Lake Okeechobee. While serving a flood control function, these canals also provide a route for supplying water when the estuaries may benefit from additional freshwater.

In order to develop environmentally sensitive water release plans from the Lake to the estuaries, biological and physical information was needed to determine a desirable range and frequency of flows. This work is summarized in Chamberlain and Doering (1998) and Haunert and Konyha (2000). In brief, the Valued Ecosystem Component approach, developed by the U.S. Environmental Protection Agency (USEPA 1987) as part of its National Estuary Program, has been used to make these determinations. The approach has been modified to focus on providing critical estuarine habitat. In many instances, that habitat is biological and typified by one or more prominent species. In other cases the habitat may be physical, such as an open water oligohaline zone. Enhancing and maintaining these biological and physical habitats should lead to a generally healthy and diverse ecosystem. Providing a suitable salinity and water quality environment for the habitat-forming species or groups of species should ensure their continued dominance. These salinity and water quality requirements form the basis for establishing minimum flows, and guidelines for discharging freshwater to estuaries.

Examples of biological habitat are oyster bars and grass beds, with prominent species being the American oyster, *Crassostrea virginica* and the SAVs, *Vallisneria americana*, *Halodule wrightii*, and *Thalassia testudinum*. The ecological functions and value of grass and oyster beds are well established (Loosanoff and Nomejko 1951, Fonseca et al. 1983, Virnstein et al 1983, Fonseca and Fisher 1986, Newell 1988, Fonseca 1989, Fonseca and Cahalan 1992 , Zieman 1982, Phillips 1984, Thayer et al. 1984, Kenworthy et al. 1988, Zieman and Zieman 1989).

Utilizing the application of the resource-based management strategy or VEC approach, a favorable range of inflow and related salinity was established. The range of flows considered necessary to maintain a favorable range of salinity is 350 cfs to 2,000 cfs for the SLE and 300 cfs to 2,800 cfs for the CE (Chamberlain and Doering 1998, Haunert and Konyha 2000).

St. Lucie Estuary Performance Measures

Consecutive days of salinity at the Roosevelt Bridge: The salinity thresholds for determining the condition of the St. Lucie Estuary are primarily based on aspects of the life history of the American Oyster, *Crassostrea virginica* (**Table 2**). This organism provides vital habitat in the St. Lucie Estuary. Information supporting these thresholds was gleaned from the general literature on oysters and it is clear from this review that the effects of salinity on oysters vary from place to place and time to time. General ranges (**Table 3**) have been identified and are thought to be reasonable for oysters from St. Lucie (URS Greiner Woodward Clyde 1999). In making the final assessment of estuarine condition other factors, such as time of year, and life histories of other important species (blue crab, sea trout) may be considered.

Table 2. Summary of salinity thresholds for the American Oyster, *Crassostrea virginica*.

Salinity Range	**Oyster Response**
> 24	Increased predation and disease
12 – 24 ppt	Good for larval development, settlement and growth of young oysters
7.5 to 12 ppt	Growth and reproduction for adults
2 to 7.5 ppt	Survival, minimal growth and reproduction
< 2 ppt	Mortality

Table 3. Salinity performance measure for the St. Lucie estuary. In the categorization scheme of this and subsequent tables, **red** = high probability of adverse impacts to the ecosystem, yellow = moderate probability of adverse impacts, and **green** = low probability of adverse impacts.

Performance Measure		Days	0	1 - 30	31 - 60
Consecutive Days of Salinity At Roosevelt Bridge		**Salinity Range**			
		> 24 ppt			
		7.5 to 24 ppt			
		2 – 7.5 ppt			
		< 2 ppt			

Minimum Flow and Level (MFL) Performance Measure: Minimum flow criteria for the St. Lucie Estuary have been developed and are used here in a performance measure (**Table 4**). Mean monthly flows of more than 28 cfs to the St. Lucie Estuary represent the amounts of water necessary to maintain sufficient salinities in the estuary in order to protect the oligohaline organisms that are valued ecosystem components of this system. If flows fall below this minimum for two consecutive months, the minimum flow criteria will be exceeded and harm occurs to the estuarine resources. If harm, as defined above, occurs during two consecutive calendar years, significant harm and a violation of the minimum flows and levels criteria occurs. Therefore, the MFL performance measure for the St. Lucie Estuary indicates if an exceedance has occurred (or is likely to occur) and identify the need to address an MFL violation (or possibly prevent it from occurring, if water is available). However, as previously stated, the long-term solution to meeting MFLs for the estuaries is CERP.

Table 4. St. Lucie Estuary Low Flow (MFL) performance measure. Color codes are defined in Table 3.

Severity Level	Number of Successive Years with Exceedances	Score in Color Code Scheme
No harm	0	
Harm	1	
Significant Harm	2	

Caloosahatchee Estuary Performance Measures

30-day Average Discharge at S-79: The discharge ranges (**Table 5**) used to assess the condition of the Caloosahatchee Estuary are based on the salinities that these discharges produce in the downstream estuary, and the effects these salinities have on beds of submerged aquatic vegetation (SAV) that are located there (Doering et al 1999, Doering and Chamberlain 2000). Effects of discharges on general water quality, bottom invertebrates, plankton and larval and juvenile fish also are considered (Chamberlain and Doering 1998). At flows below 300 cfs, saltwater can intrude into the upper estuary resulting in high salinity that damages beds of tape grass, *Vallisneria americana*. Flows greater that 2800 cfs will cause salinity to decline in the lower estuary and damage beds of the marine seagrass, *Halodule wrightii* (shoal grass). Flows greater than 4500 cfs will lower salinity further downstream in San Carlos Bay, endangering turtle grass beds (*Thallasia testudinum*).

Table 5. Caloosahatchee Estuary 30-day average discharge performance measure. Color codes are defined in Table 3.

Performance Measure		**Condition**
30 – Day Average Discharge at S-79	Mean : > 4500 cfs	
	Mean: 2800 – 4500 cfs	
	Mean : 1800 – 2800 cfs	
	Mean: 500 – 1800 cfs	
	Mean : 300 – 500 cfs	
	Mean: <300 cfs	

Minimum Flow and Level (MFL) Performance Measure: When there is not a need to discharge from the Lake for flood control purposes, opportunities for meeting MFLs also can be considered to the CE (**Table 6**). The recently adopted MFL criteria for the CE indicates a flow of approximately 300 cfs at at S-79, in combination with downstream runoff, that is expected to maintain a 30-day average salinity concentration of 10 ppt or less during the year at the Ft. Myers salinity station. If the 30-day average salinity exceeds 10 ppt or a single daily average exceeds 20 ppt, an MFL exceedance occurs. If an exceedance occurs for two consecutive calendar years, a violation of the MFL rule occurs. A flow of 300 cfs at S-79 during the months of February through April is consistent with the LECWSP. Therefore, the MFL performance measure for the Caloosahatchee Estuary indicates if an exceedance has occurred (or is likely to occur) and can identify the need to address an MFL violation (or if water is available, possibly prevent it from occurring). However, as previously stated, the long-term solution to meeting MFLs for the estuaries is CERP.

Table 6. Caloosahatchee Estuary Low Flow (MFL) performance measure. Color codes are defined in Table 3.

Severity Level	Number of Successive Years with Exceedances	Score in Color Code Scheme
No harm	0	
Harm	1	
Significant Harm	2	

5b.2 Estuary Biological Performance Measures

The hydrologic performance measures presented above are based on the relationship between hydrology and key habitat forming estuarine species. The performance of these species in the natural system serves as a measure of ecological condition. The District monitors both estuaries to quantify the performance of submerged aquatic vegetation (SAV). The performance of these species provides a measure of the success of hydrologic performance measures and the management strategies used to meet them. The results of biological monitoring signal when changes in management strategy may be required. Oysters are not currently monitored in the St. Lucie but a RECOVER monitoring plan associated with CERP is currently under development.

Caloosahatchee Estuary Biological Measures

Beds of wild celery, *Vallisneria americana*, in the upper estuary serve as the VEC upon which the minimum flow and level is based. These are monitored on a monthly frequency at 3 stations. Two permanent transects are maintained at each station. Number of shoots, number of blades, number of flowers, length of blades and width of blades are measured within quadrats at 10 random locations along each transect. The program began in 1998 and initial results are presented in Bortone and Turpin (2000).

Beds of *Vallisneria* and other more marine species of seagrass are also monitored using hydroacoustic techniques. The technique is described in Sabol et al. (2002) and allows a larger area to be sampled than is normally possible using manual techniques. The end products are GIS layers of vegetation density, canopy height and bathymetry. Two one- kilometer long reaches are mapped in each of four areas: upper estuary (*Vallisneria americana*), lower estuary (*Halodule wrightii*), San Carlos Bay (mixed *Thalassia testudinum* and *Halodule*) and Pine Island Sound (mixed *Thalassia testudinum* and *Halodule*). Beds are mapped 3 times per year.

St. Lucie Estuary Biological Measures

Oysters are not monitored in the St. Lucie but a RECOVER monitoring plan associated with CERP is currently under development. Currently, the District participates in a program that monitors seagrasses in the Indian River Lagoon twice yearly at 76 transects. Parameters measured manually include species composition, percent cover by each species, edge of bed location and shoot counts. To better understand the effects of freshwater inflow, a monthly monitoring program focused at the confluence of the St. Lucie Estuary and Indian River Lagoon began in summer 2002.

5c. Water Supply Performance Measures

A variety of approaches are used to ensure that water releases from the Lake for natural resource protection will have minimal or no impact on water supply for permitted users. Each of these approaches (regional drought index, position analysis) is described in detail, and then a set of summary performance measures is provided for integrated evaluation.

Evaluation of Regional Drought Index

The hydrologic record of South Florida includes frequent periods when rainfall is below normal for extended periods of time ranging from a few months to several years. These extended periods of rainfall shortfalls have usually ended before significant water shortages occurred. However, the South Florida hydrologic record does contain several extended periods of rainfall deficit during the 20th century that persisted long enough to cause substantial water shortages. The 1980-81, 1989-90, and 2000-01 droughts are recent examples of a prolonged period of rainfall deficit in which large cutbacks were necessary for both urban and agricultural areas in order to protect regional water resources. On an average, these events have occurred once or twice every 10 years. These more significant drought periods often begin relatively unnoticed with below normal rainfall during the wet season. Normally the Lake may gain 2 to 3 feet of storage from excess runoff from its enormous tributary basin (~4,000 square miles) during the wet season. However, when wet season rainfall is below normal, the majority of rainfall is lost to evapotranspiration with only minimum amounts of runoff actually reaching the Lake. The Lake water level may actually decline during the wet season. Since tributary conditions are the first indicator of the onset of droughts, it is critical to the regions dependent on Lake Okeechobee for water supply that releases to tide not be made during these periods even though water levels in the Lake may be slightly higher than is normally desirable for the benefit of the littoral zone.

The years of 1980, 1988, and 2000 are specific cases in which the wet season had below normal rainfall that eventually led to water shortages. In the future, until additional storage is available, Lake stages should be managed as efficiently as possible to reduce the risk of water shortage during such periods. The WSE operational schedule includes an intricate decision tree that integrates recent short-term rainfall (previous month) anomalies throughout the Lake tributaries with the available meteorological and climatic forecasts to most proficiently balance the competing objectives of water supply, flood protection, and water resource enhancement. Due to the tremendous size of the upstream tributary basin as well as the uncertainty of climate forecasts, it is concluded that the Palmer Drought Severity Index (**Appendix I**), should be monitored for existing surpluses or deficits that have accumulated from persistent rainfall anomalies. This index, although not incorporated directly into the WSE Operational Decision Tree, is useful for defining a range of opportunities within the field of discretion provided by the schedule. Using the decision tree, tributary moisture conditions would have precluded any large regulatory releases from being made prior to the four major drought periods listed above. In three of the four cases, climate forecasts would have been useful in predicting below normal rainfall for the upcoming dry season.

Although the WSE schedule calls for flexibility to be included in the implementation of operational guidelines (as indicated above in section 2), the original schedule documentation and model simulations only included performance measures for a specific set of operational rules. They did not directly include the full spectrum of operational flexibility allowed within the WSE operational guidelines. It is important that the operational flexibility be used in cases that have the potential to increase the performance of one competing objective without hurting others. **Table 7** classifies rainfall anomalies in terms of ranges of the Palmer Drought Severity Index. When estuarine, Lake, and/or Everglades performance measures indicate a need for water deliveries for natural resource protection, the current tributary condition as classified by the Palmer Index should also be considered. The Palmer Index allows the identification of meteorological drought (significantly reduced rainfall) several months before a hydrologic drought (significantly reduced reserve water storage) occurs. This allows for operational adjustments to be made while water supplies are still plentiful. Environmental water deliveries would not be made under conditions of a meteorological drought (the gray shaded boxes in **Table 7**) but could occur under more favorable meteorological conditions.

In most cases, an evaluation of current water levels in the regional system, coupled with the meteorological drought index and results from position analysis (see the following sections), will give a good indication of likely impacts of environmental water deliveries on agricultural and urban water supply. However, there may be times when the complexity of issues associated with environmental water deliveries may make it desirable to use a model to simulate a range of operational protocols, allowing the selection of the protocol that best satisfies competing objectives of Lake management. The key performance measures for water supply in such a modeling exercise are demands met and demands not met for the Lake Okeechobee Service Area (which includes the EAA) and the Lower East Coast Service Areas (1, 2 and 3).

Table 7. Classification of prolonged periods of rainfall excesses or deficits. See Appendix I for a scientific explanation of the Palmer Index.

Indicator of Persistent Meteorological Conditions during Last Several Months	Range of Meteorological Index (Palmer Drought Severity Index)	Approximate Return Period of Meteorological Condition [Average Return Period]
Extreme Drought	Less than -3.0	Less than once in 10 Years
Moderate to Severe Drought	-2.0 to -2.9	Every 5 to 10 years
Mild Drought	-1.0 to -1.9	Every 3 to 5 years
Normal	-0.9 to 0.9	Every 2 years
Noticeably Wetter than Normal	1.0 to 1.9	Every 3 to 5 years
Unusually Wetter than Normal	2.0 to 2.9	Every 5 to 10 years
Extreme Wet Period	3.0	Less than once every 10 years

Position Analysis

Position analysis (PA) (Hirsh 1978, Smith et al. 1992, Tasker and Dunne 1997, Cadavid et al. 1999) is a form of risk analysis that will be used by staff to provide additional input regarding potential effects of release decisions on agricultural and urban water supply. Given the current state of the system, position analysis evaluates the risks and potential benefits associated with specific operational plans for South Florida's water management system over a period of several months. It relies on the simulation of a large number of possible outcomes using current conditions as the initial values for modeling. To be most useful, PA needs to incorporate the broadest range of meteorological conditions that may occur in the future, but cannot be used to specifically forecast future events.

Currently, the SFWMD has the capability of running the South Florida Water Management Model (SFWMM, a regional scale hydrologic model that simulates South Florida's water management system) (SFWMD 1999) in position analysis mode. Any hydrologic variable for which SFWMM simulation output is produced could be subject to position analysis. For instance, in the case of stages in Lake Okeechobee, one daily value is extracted for a given day for every year in the simulation period (1965-1995). Empirical probability distribution functions are derived from this sample. There are 365 daily empirical distributions conditional on the initial state of the system on a specific date. Next, quantiles are obtained and time series of percentiles are assembled. These traces define the daily empirical conditional distribution and describe its evolution throughout the forecast year (**Figure 4**). A similar analysis can be applied to monthly flows or any other hydrologic variable in the system.

Percentile plots are only one way of presenting PA results. They are not designed to preserve temporal correlation in the sense that values are pulled from different years in the period of simulation. No percentile line comes from a single continuous trace; it is a combination of realizations. For this reason, it is not a good practice to infer future stages by following percentile traces for longer than a month. When these types of predictions are required, it is best to look at wet or dry year plots. These plots are constructed by sub-sampling from the period of simulation years with characteristics that closely resemble the conditions being considered. For instance, if the SFWMD is under regional dry conditions or if La Niña (below normal temperatures in the sub-surface water of the equatorial Pacific) is prevailing by the beginning of the dry season, it is advisable to examine dry year plots.

The SFWMM is run in PA mode at the beginning of each month to support the daily or anticipated operations of the SFWMD system. A typical application of the SFWMM in PA, for example, is as follows. Water managers require information on the behavior of the system for the next several months, given the initial state on October 1, 2001. The SFWMM is run for the period of simulation with October 1 stages for each year, and every cell in the modeling domain is reset to the values corresponding to October 1, 2001. A total of 30 October 1-September 30 realizations (scenarios) of system response to different hydro-climatic inputs are obtained for the 1965-1995 simulation period, each equally likely to take place in the future. Application of PA to the operations of the SFWMD is described in detail by Cadavid et al. (1999, 2001).

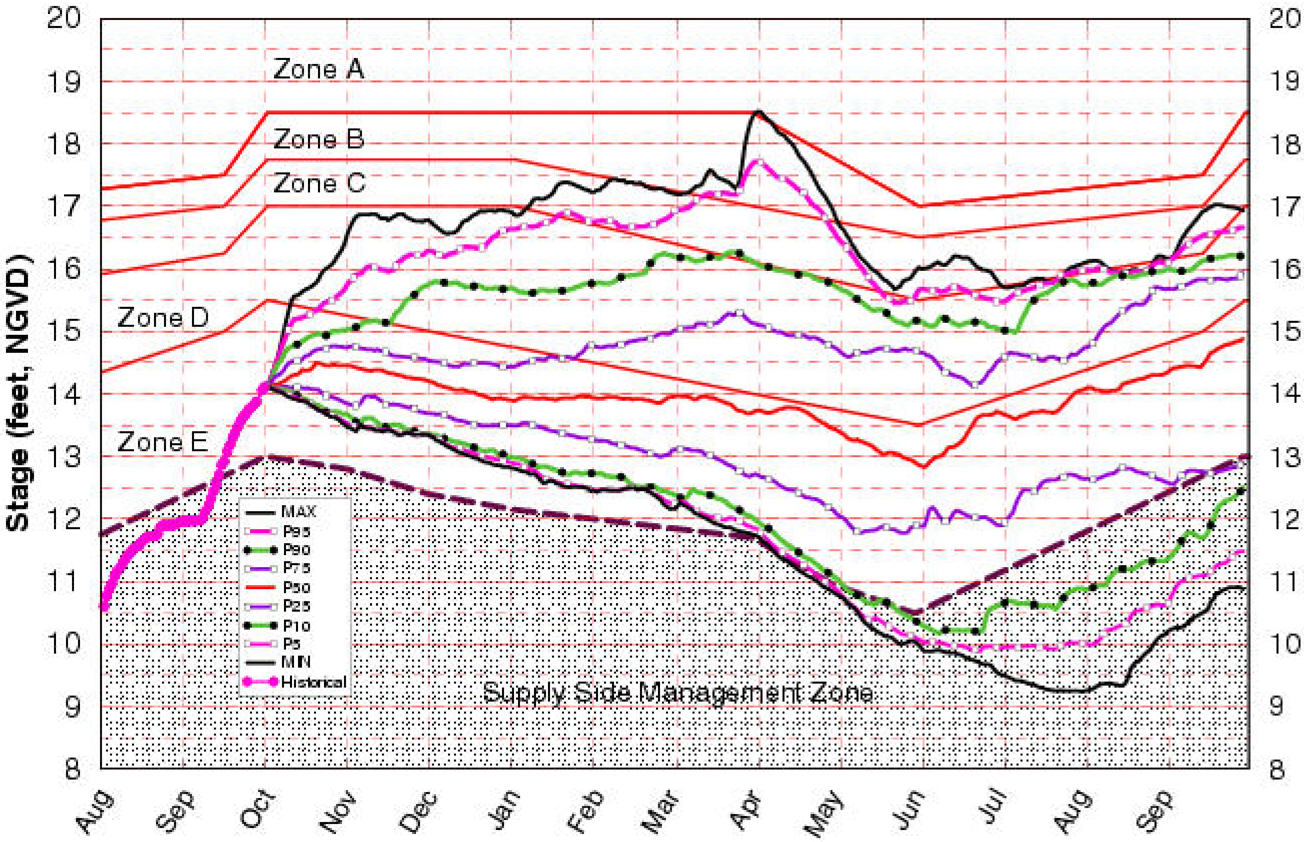


Figure 4. Lake Okeechobee stage position analysis results for October 1, 2001.

For guiding real-time operations, PA, percentile plots and other specific types of year plots can be used as decision guidance tools in determining impacts or benefits derived from specific adaptive protocols for Lake Okeechobee operations. However, the graph or type of result and how to use it depends on the operational scenario. An application example for Lake Okeechobee stage is depicted in **Figure 4**. The percentile plots provide estimates of the likelihood of Lake stage falling into different operational zones, given the current conditions in the SFWMD system. For instance, if current Lake stages are in the upper half of Zone E, the percentile plot will provide the probability and timing of going into Zone D. On the other hand, if current Lake stages are low, the percentile plot will indicate the probability of receding into the Supply Side Management Zone and the probable times when this would happen. In the case that simple operational protocols are proposed, back-of-the-envelope computations can be used to determine how such operations could modify the future likelihood of the Lake transitioning into lower or higher stages.

Evaluation of Water Supply Shortage Risk

Evaluation of water supply shortage risk is based on assigning different risk levels to a series of categories or performance measure indicators, associated with different elements in the system, such as tributary basins, storage components and different types of water users. The way in which risk levels are presented and summarized will help in the Lake Okeechobee releases decision process. The water supply risk levels considered in this evaluation are Low (L), Moderate (M) and High (H). The categories and the guidelines to assign the risk levels are presented below. The abbreviations in parenthesis represent the short name assigned to each category. If stages in the WCA's and the Lake are low, environmental water deliveries from the Lake to coastal systems (e.g., the Caloosahatchee Estuary) are considered to have a higher risk to agricultural and urban water supply than if one or both of those areas have adequate water in storage.

Performance Measure 1 -- Projected Lake Okeechobee Stage Within the Next Two Months (LOK): Obtained from the Position Analysis (PA) results and the corresponding Lake Okeechobee stage tracking chart, this indicator gives the zone within which Lake stage most likely would be during the next two months. These graphs are posted at the SFWMD web page. Possible outcomes and risk levels are as follows:

Projected Lake Okeechobee Stage for next two months	Risk Level
Zone D or Above	L
Zone E	M
SSM	H

The PA results and the tracking chart for Lake Okeechobee are posted at:

http://www.sfwmd.gov/org/pld/hsm/reg_app/opln/pa_recent.html

Performance Measure 2 -- Lake Okeechobee Tributary Conditions (TC): The Lake Okeechobee Tributary conditions are measured by the Palmer Drought Severity Index for the Lake Okeechobee tributary basins. The Palmer Drought Severity Index is obtained on a weekly basis from NOAA's Climate Prediction Center web site. Additional background information for this index is given in Section 5c and Appendix I of this document. Possible outcomes are as follows:

Palmer Index for Lake Okeechobee Tributary Basins (Palmer Index)	Range	Risk Level
Normal to Extremely Wet	>–1.0	L
Dry	-1.0 to –2.0	M
Extremely Dry	< -2.0	H

PDSI values are obtained from:

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/

Performance Measure 3 -- CPC Outlook (1-3 month) (CPC1-3): This is measured by the Climate Prediction Center's Precipitation Outlook for the 1 and 3-month windows starting with the current month for the most recent posting at

http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/seasonal_forecast.html

The risk levels for this indicator are defined as follows:

CPC Precipitation Outlook (1-3 month)	Risk Level
Normal and Above Normal (chance of being in the wettest tercile > 33%)	L
Below Normal: between 33 and 50% chance in the driest tercile	M
Greater than 50% chance of being in the driest tercile	H

Performance Measure 4 -- Lake Okeechobee Net Inflow Seasonal Forecast (LONISF): This is measured by the Lake Okeechobee net inflow seasonal forecast, as produced for the weekly implementation of WSE. The HSM Division in the Water Supply Department produces this value. Possible outcomes are as follows:

Lake Okeechobee Seasonal Net Inflow	Depth Range (feet)(*)	Storage Range (10^6 ac-ft)	Risk Level
Normal to Extremely Wet	> 1.1	>0.5	L
Dry	0 to1.1	0 to 0.5	M
Very Dry	< 0	< 0	H

(*) Volume-Depth Conversion based on average lake surface area of 467000 acres

Values for LONISF are found at:

http://www.sfwmd.gov/org/pld/hsm/reg_app/lok_reg/index.html

Performance Measure 5 -- Lake Okeechobee Net Inflow Multi Seasonal Forecast (LONIMSF): This is measured by the Lake Okeechobee net inflow multi seasonal forecast, as produced for the weekly implementation of WSE. The HSM Division in the Water Supply Department produces this value. The risk levels for this indicator are defined as follows:

Lake Okeechobee Multi Seasonal Net Inflow	Depth Range (feet)(*)	Range (10^6 ac-ft)	Risk Level
Wet	> 3.2	> 1.5	L
Normal	1.1 to 3.2	0.5 to 1.5	M
Dry	< 1.1	< 0.5	H

(*) Volume-Depth Conversion based on average lake surface area of 467000 acres

Values for LONIMSF are found at:

http://www.sfwmd.gov/org/pld/hsm/reg_app/lok_reg/index.html

Performance Measure 6 -- WCA-1 Stage (WCA-1): This is derived by using the WCA-1 current stage (average of gauges 1-7, 1-8T and 1-9) as reported by the USACE and the position of the stage with respect to the Lines 0, 1 and 2, as defined in the following table. Lines 0, 1 and 2 are shown in **Figure 5**

WCA-1 Stage	Position	Risk Level
High to Wet	Above Line 1	L
Fair	Line 1 – Line 2	M
Low	Below Line 2	H

Figure 6 compares the WCA-1 average marsh stage to the stage in the canal (1-8C), for the period December 2000 to June 2002. The graph shows that the 3-gauge average should be used as the stage indicator as long as stages are above elevation 16.0 ft.; the canal gauge should be used below 16.0 ft. Once the canal stage crosses a floor elevation of 14.0 ft, the canal gauge stage is used as the indicator to trigger a switch in the primary source for water supply releases for SA-1, from WCA-1 to Lake Okeechobee.

The 3-gauge average for WCA-1 and the stage for the canal gauge are obtained on a daily basis from the USACE web site at:

http://www.saj.usace.army.mil/h2o/

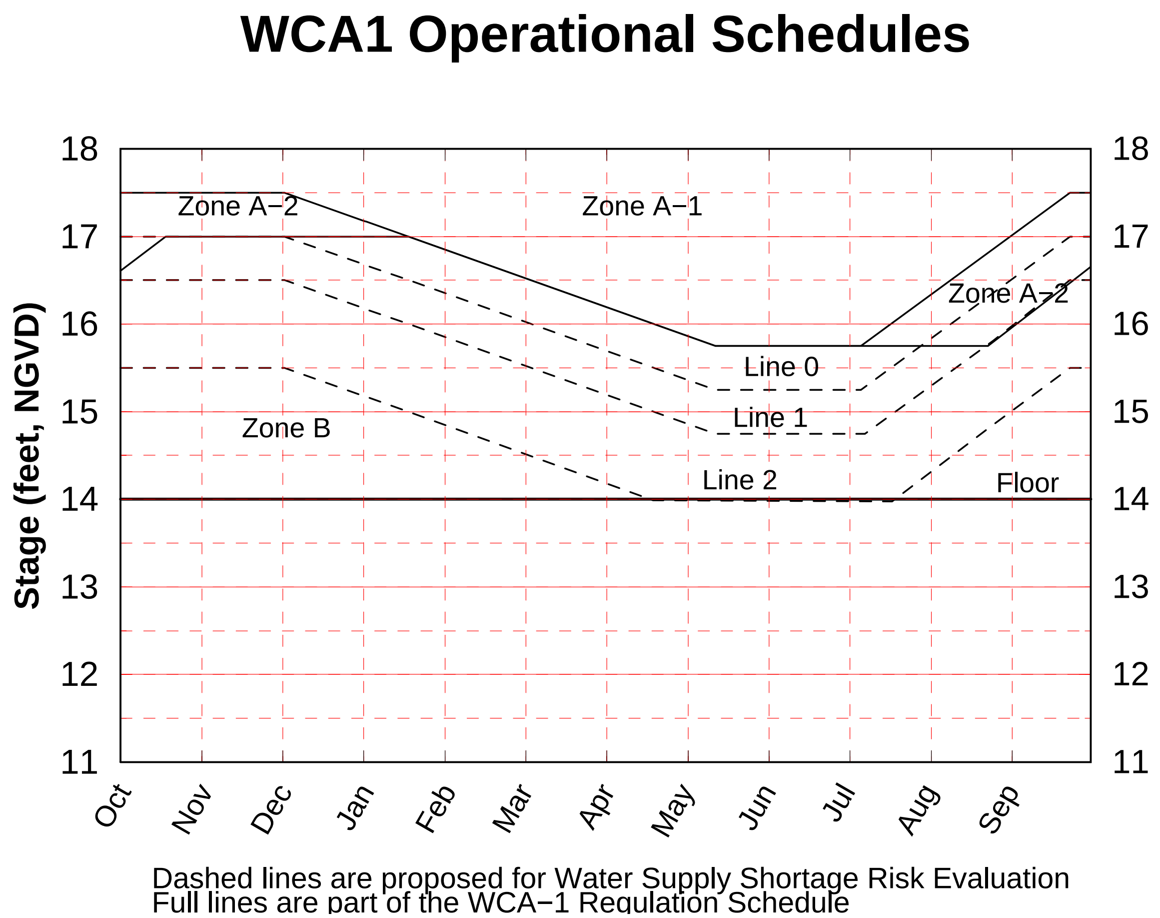


Figure 5. Proposed WCA-1 Lines for Evaluation of Water Supply Risk under Lake Okeechobee Adaptive Protocols Operations.

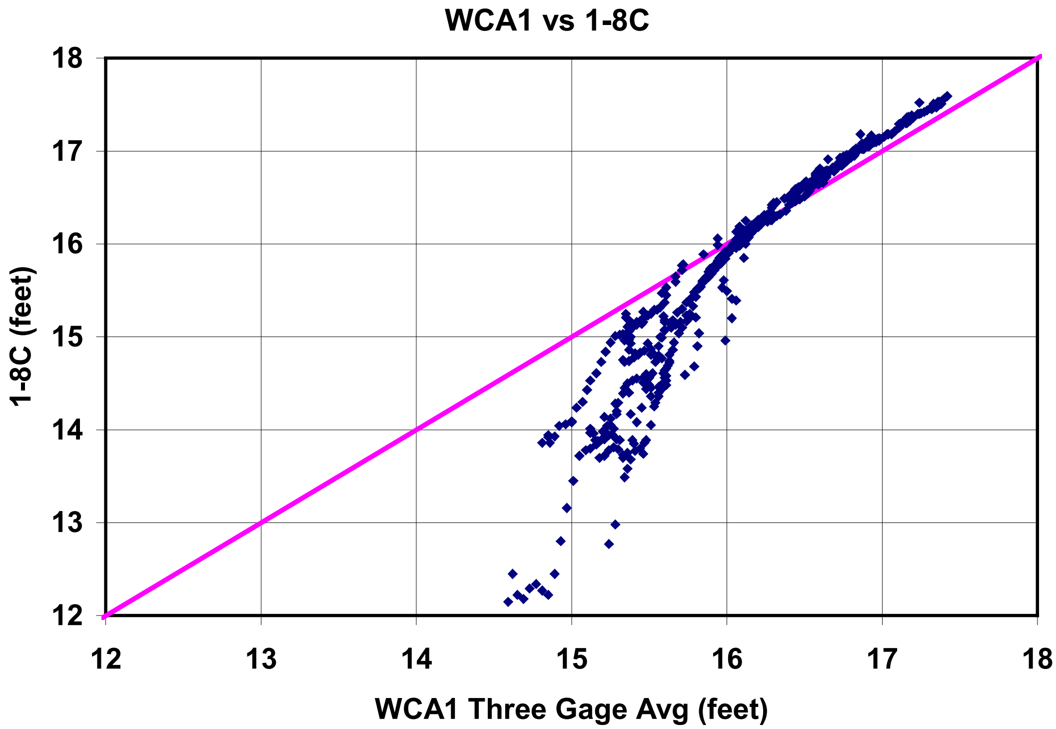


Figure 6. Comparison of historical stages in WCA-1, December 2000 to June 2002. The pink line is a 1:1 relationship.

Performance Measure 7 -- WCA-2A Stage (WCA-2A): This is measured by the WCA-2A current stage (Gauge 2-17) as reported by the USACE and the position of the Lines 0, 1 and 2, as defined in the following table. Lines 0, 1 and 2 are shown in **Figure 7**.

WCA-2 Stage	Position	Risk Level
High to Wet	Above Line 1	L
Fair	Line 1 – Line 2	M
Low	Below Line 2	H

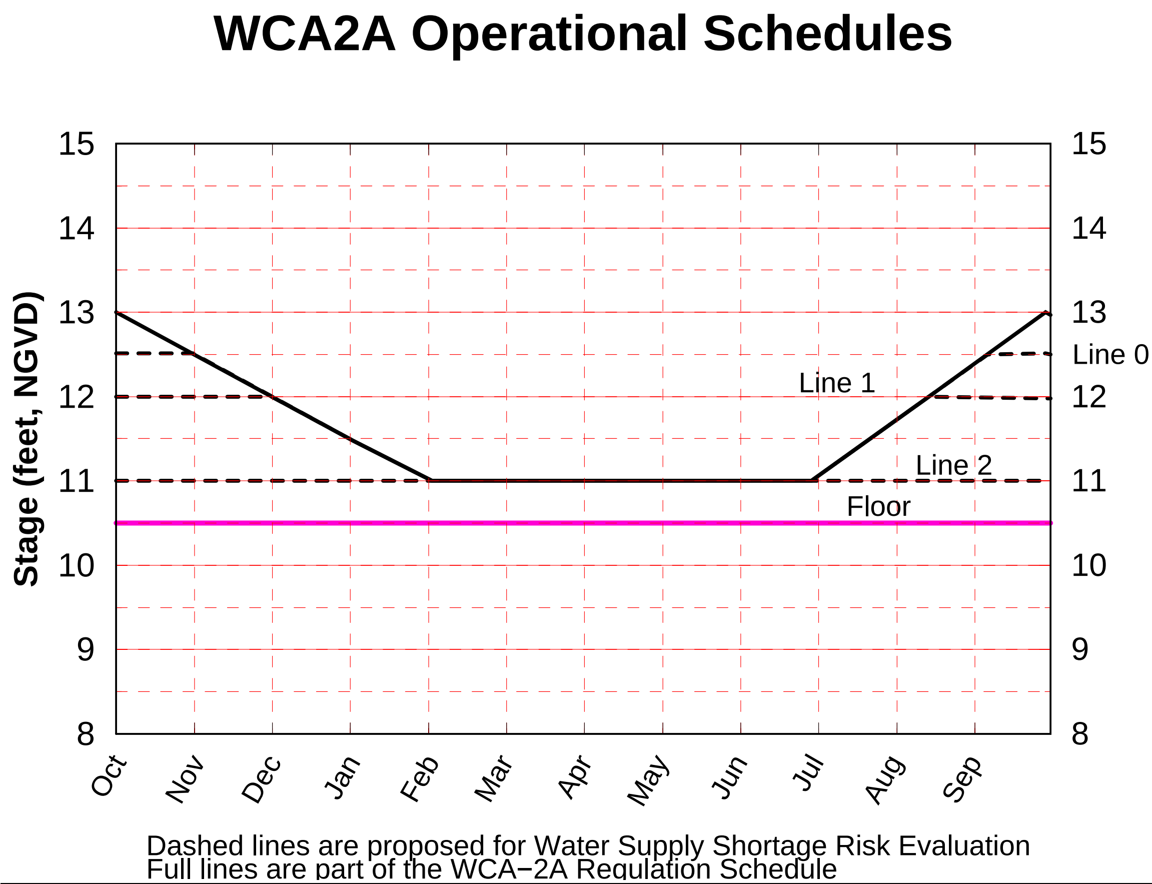


Figure 7. Proposed WCA-2A Lines for Evaluation of Water Supply Risk under Lake Okeechobee Adaptive Protocols Operations.

Figure 8 provides a comparison of the WCA-2A marsh stage (Gauge 2-17) to the stage in the canal (S-11B HW), for the period December 2000 to June 2002. The graph shows that below elevation 11.5 ft. the canal stage should be used as the indicator gauge, while above 11.5 ft. the marsh stage should be used. The canal gauge stage is used as the indicator to switch the primary source for water supply releases for SA-2 from WCA-2A to Lake Okeechobee, once the canal stage crosses the specified floor elevation of 10.5 ft.

The stage for WCA-2A and the stage for the canal gauge are obtained on a daily basis from the USACE web site at:

http://www.saj.usace.army.mil/h2o/

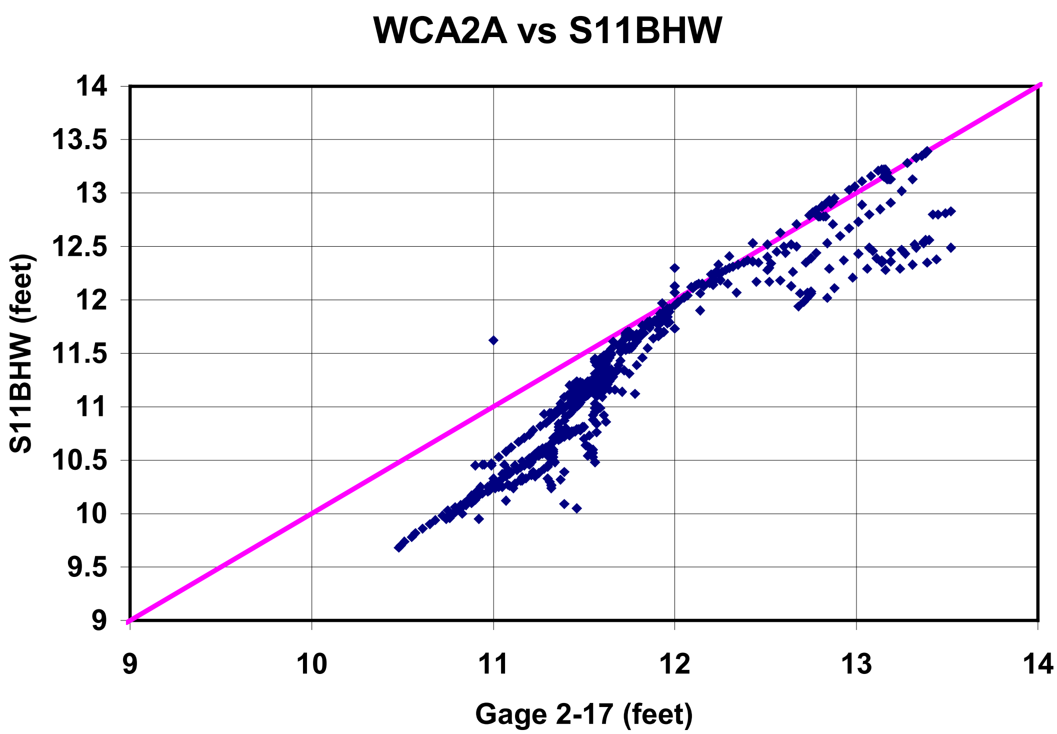
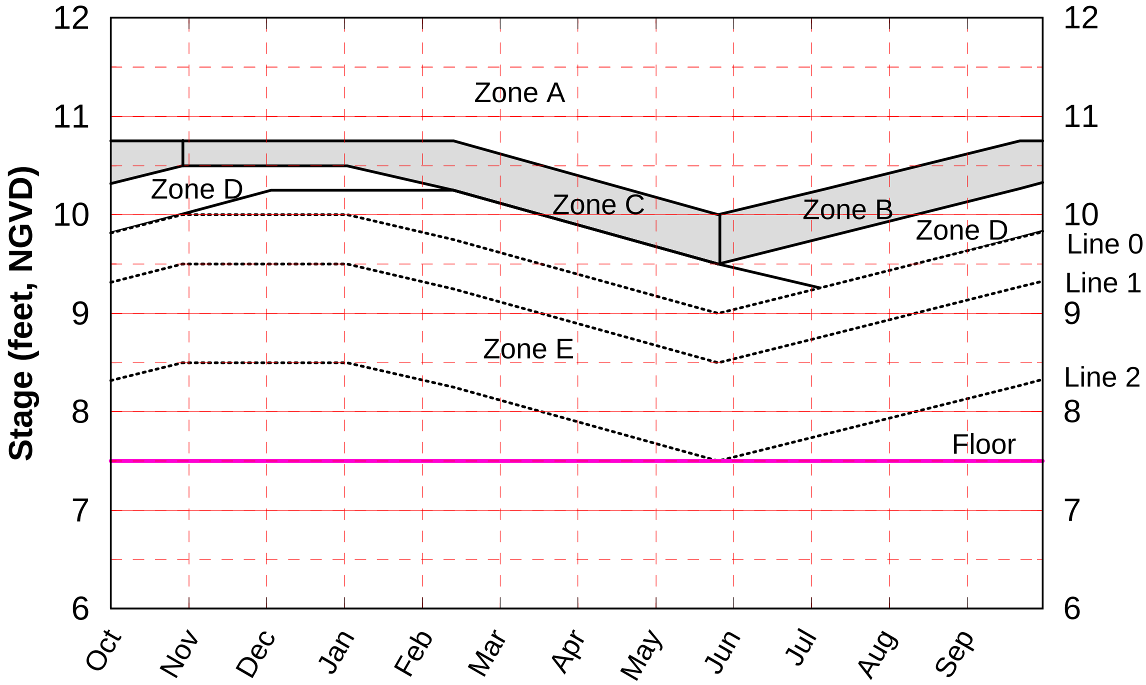


Figure 8. Comparison of historical stages in WCA-2A, December 2000 to June 2002. The pink line is a 1:1 relationship.

Performance Measure 8 -- WCA-3A Stage (WCA-3A): This is measured by the WCA-3A current stage (average of gauges 3A-3, 3A-4 and 3A-28) as reported by the USACE and the position of the stage with respect to Lines 0, 1 and 2, as shown in **Figure 9**. The risk levels for this indicator are defined as follows.

WCA-3A Stage	Position	Risk Level
High to Wet	Above Line 1	L
Fair	Line 1 – Line 2	M
Low	Below Line 2	H

WCA3A Operational Schedule



Dashed lines are proposed for Water Supply Shortage Risk Evaluation
Full lines are part of the WCA−3A Regulation Schedule

Figure 9. Proposed WCA-3A Lines for Evaluation of Water Supply Risk under Adaptive Protocols in Lake Okeechobee Operations

The canal headwater elevation at structure S-333 (S-333 HW) is used as the indicator to switch the primary source for water supply releases for SA-3 from WCA-3A to Lake Okeechobee, once the canal stage crosses the floor elevation of 7.5 ft. **Figure 10** compares these two stages, canal and marsh, for the period December 2000 to June 2002. Inspection of the graph indicates that above elevation 8.5 ft., the 3-gauge average should be used as the indicator to evaluate the risk to water supply. Below elevation 8.5 ft., evaluation should be based on S-333 HW.

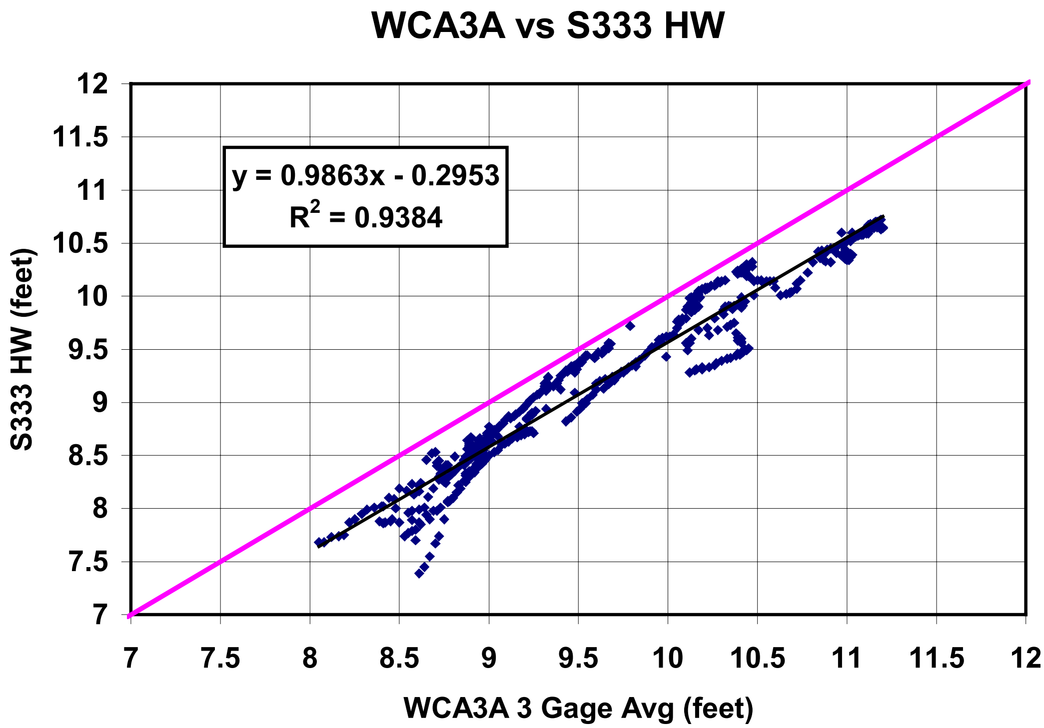


Figure 10. Comparison of historical stages in WCA-3A, December 2000 to June 2002. The pink line is a 1:1 relationship.

Performance Measure 9 -- Local Conditions in the LEC Service Areas (LECSAS): Each Service Area should be evaluated for local conditions in order to determine how close groundwater levels are to triggering local restrictions. Stages in the monitoring wells used by the SFWMD could be used here. The following table is used:

Service Area Proximity to Local Restrictions	Risk Level
Far (longer than 2 months)	L
Close (1-2 months)	M
Imminent or under Phases 1-4	H

Presentation of Indicators: Each one of the indicators described will be evaluated with the required frequency. **Table 8** gives an example of the way in which results for the Water Supply Performance Measure will be incorporated into the decision making process. Clustering the different indicator results by geographical areas will allow a quick evaluation of the conditions for different elements of the system. An evaluation of the Water Supply Risk for the entire system can also be obtained also easily from this type of presentation.

Table 9 summarizes the historical evaluation of all the indicators presented for purposes of Water Supply Risk evaluation. This provides some understanding on what to expect in the future, in terms of this methodology. It is important to emphasize that the success of this methodology is based upon frequent monitoring, processing, analysis and archiving of all the indicators

Table 8. Example reporting of the Water Supply Performance Measure. **Red** = high, yellow = moderate, and **green** = low risk.

Area	Indicator	Value	Score in Color Code Scheme
LOK	Projected LOK Stage	Upper Half of Zone E	M
	Palmer Index for LOK Tributary Conditions	-2.20 (Extremely Dry)	H
	CPC Precipitation Outlook (1-3 month)	Climatology (Normal)	L
	LOK Net Inflow Seasonal Forecast	2.0 ft. (Normal)	L
	LOK Net Inflow Multi-Seasonal Forecast	3.6 ft. (Wet)	L
WCAs	WCA-1 Stage	Above Line 1	L
	WCA-2A Stage	Above Line 1	L
	WCA-3A Stage	Above Line 1	L
LEC	Service Area 1	Far (longer than 2 months)	L
	Service Area 2	Far (longer than 2 months)	L
	Service Area 3	Far (longer than 2 months)	L

Table 9. Application of the Water Supply Performance Measure to the Period January 2000 to October 2002 (**next five pages**). Color codes are as in Table 8.

Date	LOK	TC	CPC 1-3	LONISF	LONIMSF	WCA-1	WCA-2A	WCA-3A	LECSA1	LECSA2	LECSA3
1/3/00	L	L	M	M	M	L	L	L	L	L	L
1/10/00	L	L	M	M	M	L	L	L	L	L	L
1/17/00	L	L	M	M	M	L	L	L	L	L	L
1/24/00	L	L	M	M	M	L	L	L	L	L	L
1/31/00	L	L	M	M	M	L	L	L	L	L	L
2/7/00	L	L	M	M	M	L	L	L	L	L	L
2/14/00	L	L	M	M	M	L	L	L	L	L	L
2/21/00	L	L	M	L	M	L	L	L	L	L	L
2/28/00	L	L	M	L	M	L	L	L	L	L	L
3/6/00	L	M	M	L	M	L	L	L	L	L	L
3/13/00	L	M	M	L	M	L	M	L	L	L	L
3/20/00	L	M	M	L	M	L	L	L	L	L	L
3/27/00	L	M	M	L	M	L	L	L	L	L	L
4/3/00	L	M	M	L	M	L	L	L	L	L	L
4/10/00	L	M	M	L	M	L	L	L	L	L	L
4/17/00	L	M	L	L	M	L	L	L	L	L	L
4/24/00	L	M	L	L	M	L	L	L	L	L	L
5/1/00	M	H	L	L	M	L	L	L	L	L	L
5/8/00	M	H	L	L	M	L	L	L	L	L	L
5/15/00	M	H	L	L	M	L	L	L	L	L	L
5/22/00	M	H	L	L	M	L	L	M	L	L	L
5/29/00	M	H	L	L	M	L	L	M	L	L	L
6/5/00	M	H	L	L	M	M	L	M	L	L	L
6/12/00	M	H	L	L	M	L	L	L	L	L	L
6/19/00	M	H	L	L	M	M	L	L	L	L	L
6/26/00	M	H	L	L	M	M	L	L	L	L	L
7/3/00	M	M	L	L	M	L	L	L	L	L	L
7/10/00	M	M	L	L	M	L	L	L	L	L	L
7/17/00	M	M	L	L	M	L	L	L	L	L	L
7/24/00	M	M	L	L	M	L	L	L	L	L	L
7/31/00	M	M	L	L	M	L	L	L	L	L	L

Date	LOK	TC	CPC 1-3	LONISF	LONIMSF	WCA-1	WCA-2A	WCA-3A	LECSA1	LECSA2	LECSA3
8/7/00	M	H	L	L	M	L	L	L	L	L	L
8/14/00	M	H	L	L	M	L	L	L	L	L	L
8/21/00	M	H	L	L	M	L	L	L	L	L	L
8/28/00	M	H	L	L	M	L	L	L	L	L	L
9/4/00	H	H	L	L	M	M	L	L	L	L	L
9/11/00	H	H	L	L	M	M	L	L	L	L	L
9/18/00	H	H	L	L	M	M	L	L	L	L	L
9/25/00	H	H	L	L	M	M	L	L	L	L	L
10/2/00	H	H	L	L	M	L	L	L	L	L	L
10/9/00	H	H	L	L	M	L	L	L	L	L	L
10/16/00	H	H	L	L	M	L	L	L	L	L	L
10/23/00	H	H	L	M	L	L	L	L	L	L	L
10/30/00	H	H	L	M	L	L	L	L	L	L	L
11/6/00	H	H	L	M	L	L	L	L	M	M	M
11/13/00	H	H	L	M	L	L	L	L	M	M	M
11/20/00	H	H	M	M	M	L	L	L	M	M	M
11/27/00	H	H	M	M	M	L	L	L	M	M	M
12/4/00	H	H	M	M	M	L	M	L	H	H	H
12/11/00	H	H	M	M	M	L	M	L	H	H	H
12/18/00	H	H	M	M	M	L	M	L	H	H	H
12/25/00	H	H	M	M	M	L	M	L	H	H	H
1/1/01	H	H	M	M	M	L	M	L	H	H	H
1/8/01	H	H	M	M	M	L	M	L	H	H	H
1/15/01	H	H	M	M	M	L	M	L	H	H	H
1/22/01	H	H	M	M	M	L	M	L	H	H	H
1/29/01	H	H	M	M	M	L	M	L	H	H	H
2/5/01	H	H	M	M	M	L	H	L	H	H	H
2/12/01	H	H	M	M	M	M	H	M	H	H	H
2/19/01	H	H	M	L	M	M	H	M	H	H	H
2/26/01	H	H	M	L	M	H	H	M	H	H	H
3/5/01	H	H	M	L	M	H	H	M	H	H	H

Date	LOK	TC	CPC 1-3	LONISF	LONIMSF	WCA-1	WCA-2A	WCA-3A	LECSA1	LECSA2	LECSA3
3/12/01	H	H	M	L	M	H	H	M	H	H	H
3/19/01	H	H	M	L	M	M	H	M	H	H	H
3/26/01	H	H	M	L	M	M	H	M	H	H	H
4/2/01	H	H	M	L	M	L	H	M	H	H	H
4/9/01	H	H	M	L	M	L	H	M	H	H	H
4/16/01	H	H	M	L	M	M	H	M	H	H	H
4/23/01	H	H	M	L	M	M	H	M	H	H	H
4/30/01	H	H	M	L	M	H	H	M	H	H	H
5/7/01	H	H	M	L	M	H	H	M	H	H	H
5/14/01	H	H	M	L	M	H	H	M	H	H	H
5/21/01	H	H	M	L	M	H	H	M	H	H	H
5/28/01	H	H	M	L	M	M	L	M	H	H	H
6/4/01	H	L	M	L	M	M	L	M	H	H	H
6/11/01	H	L	M	L	M	L	L	M	H	H	H
6/18/01	H	L	M	L	M	L	L	M	H	H	H
6/25/01	H	L	M	L	M	L	L	M	H	H	H
7/2/01	H	L	M	L	M	L	L	M	H	H	H
7/9/01	H	L	M	L	M	L	L	M	H	H	H
7/16/01	H	L	M	L	M	L	L	L	H	H	H
7/23/01	H	L	L	L	M	L	L	L	H	H	H
7/30/01	H	L	L	L	M	L	L	L	H	H	H
8/6/01	H	L	L	L	M	L	L	L	H	H	H
8/13/01	H	L	L	L	M	L	L	L	H	H	H
8/20/01	H	L	L	L	M	L	L	L	H	H	H
8/27/01	H	L	L	L	M	L	L	L	H	H	H
9/3/01	M	L	L	L	M	L	L	L	H	H	H
9/10/01	M	L	L	L	M	L	L	L	H	H	H
9/17/01	M	L	L	L	M	L	L	L	H	H	H
9/24/01	M	L	L	L	M	L	L	L	H	H	H
10/1/01	M	L	L	L	M	L	L	L	L	L	L
10/8/01	M	L	L	L	M	L	L	L	L	L	L

Date	LOK	TC	CPC 1-3	LONISF	LONIMSF	WCA-1	WCA-2A	WCA-3A	LECSA1	LECSA2	LECSA3
10/15/01	M	L	L	L	M	L	L	L	L	L	L
10/22/01	M	L	M	M	L	L	L	L	L	L	L
10/29/01	M	L	M	M	L	L	L	L	L	L	L
11/5/01	M	L	M	M	L	L	L	L	L	L	L
11/12/01	M	L	M	M	L	L	L	L	L	L	L
11/19/01	M	L	M	M	L	L	L	L	L	L	L
11/26/01	M	L	M	M	L	L	L	L	L	L	L
12/3/01	L	L	M	M	M	L	L	L	L	L	L
12/10/01	L	L	M	M	L	L	L	L	L	L	L
12/17/01	L	L	M	M	M	L	L	L	L	L	L
12/24/01	L	M	M	M	M	L	M	L	L	L	L
12/31/01	L	M	M	M	M	L	M	L	L	L	L
1/7/02	L	M	M	M	M	L	M	L	L	L	L
1/14/02	L	M	M	M	M	L	M	L	L	L	L
1/21/02	L	M	M	M	M	L	M	L	L	L	L
1/28/02	L	M	M	M	M	L	M	L	L	L	L
2/4/02	L	M	M	M	M	L	M	L	L	L	L
2/11/02	M	M	M	M	M	L	M	L	L	L	L
2/18/02	M	M	L	L	M	L	M	L	L	L	L
2/25/02	M	L	L	L	M	L	M	L	L	L	L
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3/25/02	M	M	L	L	M	L	M	L	L	L	L
4/1/02	M	H	L	L	M	L	M	L	L	L	L
4/8/02	M	H	L	L	M	L	L	L	L	L	L
4/15/02	M	H	L	L	M	L	L	L	L	L	L
4/22/02	M	H	L	L	L	L	H	L	L	L	L
4/29/02	M	H	L	L	L	H	H	M	L	L	L
5/6/02	M	H	L	L	L	H	H	H	L	L	L
5/13/02	M	H	L	L	L	M	H	M	L	L	L

Date	LOK	TC	CPC 1-3	LONISF	LONIMSF	WCA-1	WCA-2A	WCA-3A	LECSA1	LECSA2	LECSA3
5/20/02	M	H	L	L	L	M	H	M	L	L	L
5/27/02	M	H	L	L	L	H	H	M	L	L	L
6/3/02	M	H	L	L	L	M	H	L	L	L	L
6/10/02	M	H	L	L	L	L	L	L	L	L	L
6/17/02	M	H	L	L	M	L	L	L	L	L	L
6/24/02	M	L	L	L	M	L	L	L	L	L	L
7/1/02	M	L	L	L	M	L	L	L	L	L	L
7/8/02	M	L	L	L	M	L	L	L	L	L	L
7/15/02	M	L	L	L	M	L	L	L	L	L	L
7/22/02	M	L	L	L	L	L	L	L	L	L	L
7/29/02	L	L	L	L	L	L	L	L	L	L	L
8/5/02	L	L	L	L	L	L	L	L	L	L	L
8/12/02	L	L	L	L	L	L	L	L	L	L	L
8/19/02	L	L	L	L	L	L	L	L	L	L	L
8/26/02	L	L	L	L	L	L	L	L	L	L	L
9/2/02	L	L	L	L	L	L	L	L	L	L	L
9/9/02	L	L	L	L	L	L	L	L	L	L	L
9/16/02	L	L	L	L	L	L	L	L	L	L	L
9/23/02	L	L	L	L	L	L	L	L	L	L	L
9/30/02	L	L	L	L	L	L	L	L	L	L	L
10/7/02	L	L	L	L	L	L	L	L	L	L	L
10/14/02	L	L	L	L	L	L	L	L	L	L	L
10/21/02	L	L	L	L	L	L	L	L	L	L	L

5c. *Everglades Protection Area*

Performance measures for the Everglades Protection Area are based on published technical information as well as best professional judgment and are intended to be used as guidance for water management decisions within the scope of current regulatory requirements, operational logistics, and remediation technology.

5c.1 Everglades Hydrologic Performance Measures

Hydrologic performance measures for the Everglades are documented in the C&SF Project Comprehensive Review Study (USACE 1999) and the Everglades Ridge and Slough Conceptual Ecosystem Model (Davis 2000) for the Restoration Coordination and Verification (RECOVER) program of CERP. They are based on numerous runs of the Natural System Model (NSM) and over a decade of rigorous science and peer-reviewed literature (e.g., Swift and Nicholas 1987, Urban et al. 1993, Davis and Ogden 1994, Newman et al. 1998, Gawlik and Rocque 1998, Sklar et al. 2002). The following narrative describes their scientific basis and the approach for using them as part of the Adaptive Protocols. Along with the hydrologic performance measures, assessment of the Everglades ecological status will be based on a set of biological indicators, including tree islands, wading bird foraging requirements, peat loss, emergent wetland plants, and nutrient concentrations. All of this information will be taken into consideration in regard to water releases from Lake Okeechobee to the Everglades ecosystem.

There are three hydrologic performance measures. Two of these relate to impacts associated with extreme high and low water, and one identifies a desired spring recession rate of 3.5 cm per week, which has documented impacts associated with wading bird foraging and nesting success.

<u>Extreme High or Low Stages</u>

As wetland soils are exposed to air, the oxidation of organic matter accelerates, which results in soil loss and an increase in bio-available P (inorganic forms) (Newman et al. 1998, Newman et al. 2001). In addition, structural changes may occur during the process of consolidation and compaction, which results in decreased soil porosity and some irreversible loss of water-holding capacity (Kushlan 1990 and references therein). Another consequence of low stages is a loss of dry season aquatic refugia, and an increased potential for peat-fire. Although these disturbances occurred in the historic Everglades, their frequency is thought to have increased as a result of altered hydrology (Alexander and Crook 1974, Gunderson and Snyder 1994). Moreover, recovery from peat-fire in present times can be difficult in the face of existing levels of marsh degradation. For example, where peat-fire may have once simply converted sawgrass stands into sloughs through elevation changes, it may now encourage the opportunistic expansion of cattail that can be supported by high antecedent levels of soil P (Smith et al. 2001, Smith and Newman 2001).

For aquatic organisms, reduced water depths and/or hydroperiod typically lead to diminished population size, particularly of small fishes (Loftus and Eklund 1994). When surface water disappears, the use of foraging sites by wading birds decreases rapidly (Bancroft et al. 1994). Under these circumstances, birds will fly increasing distances from the colony to find suitable foraging habitat (i.e., presence of surface water). At some distance from the nest, however, it becomes energetically unprofitable to transport food to the young. In addition, nesting sites are adversely impacted when surface water directly under a colony site is absent, thus providing access to mammalian predators (Rodgers 1987, Frederick and Collopy 1989). Under these conditions the adults will abandon the nesting colony (Bancroft et al. 1994).

Abnormally high stages similarly cause biological degradation. Deep water inhibits tree island seed germination, sapling growth, and induces high levels of physiological stress in many tree species (Craighead 1971, Gunderson et al. 1988; Worth 1987). Wading bird prey becomes dispersed, which reduces foraging efficiency and subsequent nesting success during the breeding season (Kushlan 1976a, Kushlan 1986, Hoffman et al. 1994, Gawlik in review). In addition, deer populations can be adversely affected by high-water conditions (Light and Dineen 1994). For the Cape Sable Seaside Sparrow, an endangered species, areas of dry ground are an absolute requirement during the nesting season from mid-March to mid-June (Kushlan and Bass 1983, Nott et al. 1998, Stevenson and Anderson 1994). Sparrow habitat conditions have generally been assessed by stage readings from gauges that are in close proximity to various sub-populations. Water management operations must attempt to provide for suitable breeding habitat and remedy any situations where water levels exceed ground levels in critical areas. In this regard, specific operating procedures have been outlined and continue to undergo further refinement (Dial Cordy & Associates 2000).

Natural System Targets

One approach that has been used to identify desirable hydrologic conditions that would benefit the physical, chemical and biological components of the ecosystem is the use of the Natural Systems Model (NSM). The NSM was developed to provide an estimate of pre-drainage flows and stages throughout the Everglades system, prior to human influence on the landscape (Fennema et al. 1994). The NSM (version 4.5) uses the same calibrated algorithms as those incorporated in the South Florida Water Management Model (SFWMM) to represent surface and ground water flows within the region, except that roads, canals, water management structures, and urban well fields are not contained in the NSM. Estimates of pre-drainage soil topography and historical Everglades landscape vegetation communities are also incorporated into the NSM. Output from the NSM includes surface and ground water levels at various locations as well as overland flow, ground water flow, and evapotranspiration. The NSM uses recent rainfall data (1965-1995) to predict how water would flow through an unmodified South Florida's hydrologic system. The NSM is regarded as the most comprehensive tool available that describes the hydrology of South Florida prior to human influence and, therefore, provides a reasonable estimate of the hydrologic patterns needed to restore the ecosystem.

The NSM output has been used as planning targets for both the C&SF Comprehensive Review Study (USACE 1999) and the LECRWSP (SFWMD 2000a). For the purposes of this report, the modified NSM stage targets as presented in the LECRWSP were used to estimate target stages for a network of gauges within the Everglades Protection Area (EPA). For the purpose of evaluating EPA performance in the Adaptive Protocols, deviations between the LECRWSP-based restoration targets and actual stages of EPA indicator gauges will be evaluated (**Appendix II, Figure II-1**). In this way, hydrologic performance measures will be directly tied to both the CERP and LECRWSP restoration objectives and will integrate the needs of many different users (i.e., flora and fauna, as well as water supply users) on a temporal and spatial basis.

Extreme Low Stage

Providing water flows and stages to meet statutorily defined Minimum Flows and Levels (MFL) criteria were also considered an important component of the Adaptive Protocols. Generally stated, a MFL for a given watercourse or aquifer shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area (Chapter 373.0421 Florida Statutes). On September 10, 2001, the Governing Board of the SFWMD adopted Rule 40E-8, which defines MFL criteria for the Everglades as well as Lake Okeechobee, the Biscayne aquifer and the Caloosahatchee River. **Appendix II, Table II-1** provides a summary of these criteria for the EPA.

MFL criteria established for the EPA are based on the protection of Everglades hydric soils (organic peat and marl) due to the fact that (a) over 90% of the soils within the EPA are comprised of either peat or marl, and (b) most of the plants and animals which inhabit the Everglades region depend, at least in part, on the hydrologic regime that produces hydric soils. Therefore, maintenance of a hydrologic regime, which protects these soils from significant harm, will also help protect Everglades plant and animal communities and their habitat.

MFL Criteria for Peat-Forming Wetlands: Water levels within wetlands overlying organic peat soils within the water conservation areas, Rotenberger and Holey Land wildlife management areas, and Shark River Slough (Everglades National Park) shall not fall 1.0 feet or more below ground surface, as measured at various key gauges as shown in **Figure II-1** (**Appendix II**), for one or more days during a period in which the water level has remained below ground for a minimum of 30 days, at specific return frequencies as specified in **Appendix II, Table II-1**.

MFL Criteria for Marl-Forming Wetlands: Water levels within marl-forming wetlands that are located east and west of Shark River Slough, the Rocky Glades, and Taylor Slough within Everglades National Park shall not fall 1.5 feet below ground surface, as measured at a key gauge (Figure II-1, Appendix II), for one or more days during a period in which the water level has remained below ground for a minimum of 90 days, at specific return frequencies for different areas, as identified in **Appendix II, Table II-1.**

The MFL criteria are based on existing changes and structural alterations to the pre-drainage conditions of the Everglades. It is the District's intent through implementation of the LECRWSP and the CERP to achieve minimum hydropattern return frequencies that approximate CERP-compatible, pre-drainage conditions in the Everglades. It is appropriate to use both the Everglades MFL criteria and NSM-based hydropattern targets as performance measures in the Adaptive Protocols. The categorization of hydrologic performance can then be done according to the ability of the system to meet these criteria. MFLs can be incorporated into the mix when water depth thresholds, duration and return frequency criteria are violated (**Table 10**).

Table 10. Everglades hydrologic performance measures. The color categories indicate the probability of adverse impacts, as in Table 1.

Standard deviations from LEC2020 restoration target stages*

0-0.5 (±)	
0.5-1 (±)	
1-2 (±) or when MFL criteria not met	

Number of years category is red for 3 or more months*

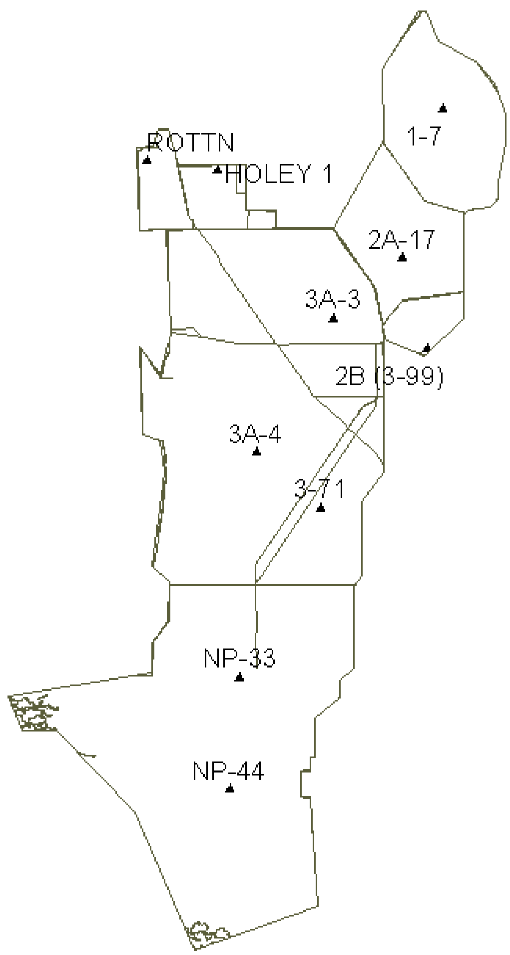
1	
2	
3	

* Note: construction limitations and/or canal conveyance constraints will prevent, in many cases, the restoration targets from being met before completion of certain CERP and LECRWSP projects.

The following gauges (**Figure 11**) are used to assess performance for individual areas of the EPA:

WCA1 – 1-7	WCA2A – 2-17
WCA-2B – 3-99	WCA-3A (north) – 3A-3
WCA-3A (south) – 3A-4	WCA-3B – 3-71
Holeyland – Holey 1	Rotenberger – Rott.N
ENP (north) – NP-33	ENP (south) – NP-44

Figure 11. Locations of gauges in the EPA for assessing hydrologic performance.



Spring Recession

Spring recession rates are an additional performance measure (**Table 11**) of marsh hydrology. A rapid rate of receding water often translates into high levels of nesting success in wading bird populations (Kahl 1964, Frederick and Spalding 1994). When the recession rate drops below 3.5 cm/week or reverses, however, aquatic prey becomes less concentrated, foraging efficiency is reduced, and nest abandonment is likely to occur (Kushlan 1976b, Frederick and Collopy 1989a, Frederick and Collopy 1989b). Recession rates for each Everglades region can be calculated from the network of gauges discussed in the previous section.

Table 11. Recession performance measures for the Everglades. Color categories are as defined in Table 1.

Stage change during February-June (cm/week)

> 3.5	
< 3.5	

Number of years category is red for 1 or more months

0	
1	
2 or more	

5c.2 Everglades Water Quality and Biological Performance Measures

Water Quality

The Everglades evolved as an oligotrophic, phosphorus-limited ecosystem. Elevated levels of phosphorus in water and soils, therefore, can produce negative ecological changes (eutrophication), typically observed as imbalances in microbial, floral, and faunal communities (Browder et al. 1994, Davis 1994, White 1994, McCormick et al. in press). Accordingly, discharges from Lake Okeechobee to the Everglades Protection Area should be made in a manner that reduces phosphorus concentrations to the greatest extent possible. Phosphorus concentrations could be reduced by routing Lake discharges through stormwater treatment areas (STAs) before entering the Everglades Protection Area. Priority should be given to routing discharges from the Lake through the STAs that have been shown to be most effective at reducing phosphorus concentrations. For example, if STAs 2 and 6 have achieved the lowest phosphorus concentrations over the past several months, discharges through these STAs should be considered preferable to discharges through other STAs.

Treatment of discharges to the EPA should be considered in the following order, from most desirable to least desirable:

(a) discharges through the top performing STAs (most desirable)
(b) discharges through other STAs
(c) discharges directly from Lake Okeechobee to the EPA (least desirable)

The impacts of phosphorus loading result from a range of spatial and temporal variables. It is important to note that for discharges of any kind, water quality impacts are dependent upon (1) volumes of discharge (loads) and (2) location of discharge. For example, receiving areas may not display any negative responses to high phosphorus concentrations, if discharges are of short duration (i.e., small loads) or if the area is already impacted. With respect to the latter, it is equally important to note that as soils and vegetation become phosphorus-saturated, the long-term effects of such activity can include expansion of the impacted zone into more pristine areas of the receiving area. These factors, although not included in this document as ranking criteria, are an important consideration in any water management decision and associated water quality performance evaluations.

Tree Islands

An important performance measure for Adaptive Protocols is tree island health in WCA-3 (Sklar and van der Valk 2002). A tree island monitoring program has been developed and implemented by SFWMD staff for WCA-3A and WCA-3B. Data on litterfall and growth rates have been collected since 1999 and used to evaluate total island response and individual species response to seasonal and long-term hydrologic regimes. Programs are also in place to examine changes in vegetation composition, canopy density, and pore-water chemistry as a way to ascertain island health and sustainability. These data have been combined into a landscape model that simulates the long-term competitive interactions between major habitat types such as, tree islands, cattail marsh, sawgrass marsh and open water slough habitats (Wu et al. 2002). The model indicated that a “generic-average tree island” is likely to experience some physiological stress and replacement by cattail or sawgrass if water levels exceed 30 cm for more than 120 contiguous days. Most importantly, two or more years of continuous high flooding can result in tree island loss. It is also recognized that extremely long hydroperiods can interfere with seed germination and the recruitment of new trees to an island (Conner 2002).

Tree islands provide critical habitat for numerous species of mammals and reptiles. Extreme high stages can prevent mammals from foraging and breeding in the EPA. The Florida Game and Fish Conservation Commission has a monitoring program for deer that provides information on the total number of deer fatalities associated with a lack of refugia and food. These data, combined with a CERP program to evaluate herpetofauna (esp. alligators and turtles) nesting characteristics in relation to stage and hydroperiods, will become a regular component of a tree island performance measure for Adaptive Protocols.

Wading Birds

Performance measures for restoration of the Everglades ridge & slough landscape include targets for wood storks, ibis, herons, and egrets. As a CERP goal of sustained nesting in the Everglades these targets should supplement the Everglades Spring Recession performance measure mentioned above. There are two performance measures for water patterns during the wading bird nesting season (Feb 1 – May 15). First, the number of water level reversals that occur as the result of water management activities during the dry down, with the ultimate goal of zero reversals. Water level reversals > 1.5 cm during the nesting season can cause wading birds to abandon nests (Kushlan 1986). Second, a strong wading bird nesting effort seems to occur when water levels during mid-March (nesting initiation) are within a certain window, which differs by region. In WCA 1, water levels for March 15th between 15.5 - 16.4 ft. at gauge 1-9 with a strong recession rate thereafter (roughly 3.5 cm/week) is optimal. In WCA 3, water levels for March 15th between 9.3 - 10.5 ft. at gauge 3A-4 with a strong recession rate thereafter is optimal. Providing optimal water levels in March with a strong water recession and no artificial reversals during the nesting season should provide wading birds with the opportunity for good nesting. However, extremes water events have always occurred in the Everglades and are probably beneficial to the system when they occur at frequencies predicted by the NSM. Historical data show that there have always been years with poor wading bird nesting events. Extreme water events in the Everglades should occur at appropriate frequencies.

Ratio of Cattail to Sawgrass (C/S)

Lake releases to the Everglades can enhance the spread of cattails through a variety of mechanisms. Cattail are better "equipped" to deliver oxygen to their roots than sawgrass (Sklar et al. 2000) therefore, lake releases that result in very high stages may increase the C/S ratio, especially where soil nutrients are relatively high. Where sawgrass has just burned, a rapid increase in water depth will actually kill the sawgrass (Herndon et al 1991, Gunderson and Synder 1994, 404 field observations 2001) and increase the C/S ratio.

One goal of the Phosphorus Threshold Program (PTP) of the Everglades Forever Act (EFA) is to show net improvement in areas already impacted by P, e.g., prevent further expansion of the "impacted cattail" zone of the Everglades. WCA-2A is the most nutrient enriched region of the Everglades. While P loads to this region have remained elevated, the nutrient front, as evidenced by cattail expanse and soil nutrient status, has been shown to be continuing to expand (Rutchey and Vilchek 1999, DeBusk et al. 2001). Research is currently underway to determine the ability to improve the habitat quality of these cattail dominated regions, while minimizing further expansion of this region. A field trial to examine the ability to maintain open water habitat within dense cattail areas is the first step in this research effort.

Adaptive Protocols for a C/S performance measure will use the PTP monitoring program and the 404 Permit monitoring program to supply current C/S data. These monitoring programs examine the vegetation trends in relation to hydrology and water quality and can be used as input to real-time system management. Biannual aerial photography and GIS will supplement these data by providing information on the total extent of these high C/S zones.

The effects of human-induced P enrichment are most evident in the northern Everglades. Ecological responses; surface and porewater nutrient changes, periphyton, macrophyte and invertebrate community composition, soil nutrient status, diel oxygen characteristics, to P enrichment are being measured along existing nutrient gradients (McCormick et al. 1996; McCormick et al. 1997, McCormick et al. 1998, Miao and Sklar 1998 , McCormick et al. 1999, McCormick et al. 2001, Newman et al. 2001a, Newman et al. 2002). This extensive peer-reviewed research and monitoring program has been under way in WCA 2A since 1994 and in the LNWR since 1996. In 1999, a one year study was initiated in WCA 3A and Taylor slough (Everglades National Park) to assess whether the southern Everglades would have similar sensitivity to P enrichment and determine whether marl-based wetlands would respond differently than peat-based wetlands.

The 404 monitoring and research program, created to document biological changes downstream of the Stormwater Treatment Areas (STAs), is located in western Water Conservation Area 2A and STA5, adjacent to the Rotenberger Wildlife Management Area. Permanent monitoring stations established along these hydrologic and water quality gradients measure water quality, hydrology, soils, periphyton and macrophytes. Surface water quality samples are collected monthly. Porewater and diel oxygen profiles are collected quarterly. Periphyton is also sampled quarterly for nutrients, chlorophyll production and taxonomy. Soil cores are collected on an annual basis. Several types of macrophyte sampling techniques are utilized to monitor changes in species composition and physiological processes. Both a macrophyte biomass harvest (aboveground biomass and nutrients) and permanent vegetation plots (species composition, growth rates) are conducted annually. A general plant survey around each monitoring station is performed twice a year. Shoot re-growth is also measured on sawgrass and cattail plants twice a year. Additionally, aerial mapping is performed in both areas to document changes in cattail coverage.

5e. STA Performance Measures

Within the scope of the Lake Okeechobee operations, water deliveries will be made to the STAs. A general discussion of water supply deliveries needed to prevent dryout of the STAs is provided in the LECRWSP (SFWMD, May 2000). Additional information is provided below.

The STAs are part of the overall Everglades protection program mandated by the 1994 Everglades Forever Act and the 1991 Settlement Agreement to the Federal Everglades lawsuit (amended 2001). The STAs, as part of the Everglades Construction Project, are large constructed wetlands designed to reduce phosphorus concentrations in stormwater originating from the EAA, C-139 and Western C-51 basins, as well as releases from Lake Okeechobee, prior to discharging into the Water Conservation Areas of the Everglades Protection Area. There are state and federal regulatory and legal requirements to ensure the STAs operate effectively at removing phosphorus. The biological phosphorus removal mechanism within each STA requires sustained growth of vegetation and accumulation of biomass. Water reservations from Lake Okeechobee for the STAs will be needed to maintain the water quality functions of the STAs and reduce the potential for nutrient releases associated with dry periods.

The long term phosphorus removal mechanism for the STAs is the growth and subsequent deposition of organic matter as new sediment - in short, accumulation of biomass. To ensure that the organic sediment does not release phosphorus on exposure to air, the operational target for the STAs is to maintain a minimum depth of six inches. The potential impacts of dry out within the STAs will vary depending on site-specific soil, vegetation and hydrology. Those impacts may include:

(a) death of wetland vegetation due to dehydration;
(b) growth of undesirable vegetation (exotics, dog fennel, and other terrestrial species) as the organic soil is exposed to the air;
(c) resuspension of phosphorus from the soil into surface waters upon re-wetting;
(d) a period following re-flooding, lasting a year or more, during which time phosphorus reduction may be greatly reduced, depending on the severity of the drought and the health of the vegetation. Upon re-wetting, it may be necessary to take individual treatment cells off line as the STA vegetation re-grows before the cell produces a net reduction in phosphorus as required by permit.

There also is evidence that dry out and subsequent re-wetting of an STA may stimulate the mercury methylation process, which in turn may induce potential risks to wildlife on-site and in the downstream Everglades.

<u>STA Performance Measure 1 – Water Depths</u>

The success of STAs in removing phosphorus is directly linked to the health and viability of the vegetated communities within the STAs. Three general types of vegetated communities are used in the STAs: cattail, sawgrass and other marsh species, and submerged aquatic vegetation (SAV). Even during dry weather (including drought conditions), it is important that these vegetated communities receive water to ensure that they will be effective in removing phosphorus during future storm events. There are three critical water depth thresholds used in operating the STAs.

Optimal performance. For optimal phosphorus removal performance, it is desired to maintain operating depths of 18 to 24 inches above average ground level.

Net improvement. A sub-optimal performance threshold is for STA outflow concentrations to be marginally better than inflow, thereby ensuring there is a slight net improvement. To minimize the potential for organic sediment within the STAs to release phosphorus upon exposure to the air, a minimum depth of 6 inches above average ground level is to be maintained whenever possible.

Vegetation viability. Based on best available scientific information, the three vegetation communities have unique minimum depths required to keep the vegetation alive (**Table 12**). For cattail, a stress threshold is approximately 6 inches below ground. For SAV, a mortality threshold is approximately 6 inches above ground. For sawgrass and other mixed marsh species, it appears that there is no mortality threshold.

Table 12. Relationships between health of various vegetation types and water level in the STAs.

Vegetation Type	Optimal Performance	Net Improvement	Vegetation Stress or Mortality
Cattail	12-18 inches above ground	6 inches above ground	6 inches below ground
Sawgrass and mixed marsh	12-18 inches above ground	6 inches above ground	No minimum depth
Submerged Aquatic Vegetation	18-24 inches above ground	6 inches above ground	6 inches above ground

Estimates of Supplemental Deliveries to the STAs

During the dry season or in periods of drought, water supply deliveries from the Lake can effectively maintain the necessary water depths within the STAs. It is anticipated that the volume of Lake Okeechobee water necessary to maintain the water quality function of the STAs (**Table 13**) will be considerably less than other water supply deliveries from the Lake.

Table 13. Simulated Mean Annual Water Supply from Lake Okeechobee to Maintain Minimum 0.5-ft Depth (based on December 2001 BASERR2R 1965-1995 simulation results of the South Florida Water Management Model).

STA	Average Supplemental Water Delivery acre-ft/yr	Maximum Annual Delivery acre feet	Average Demand Not Met acre-ft/yr
STA-1E	367	4301	219
STA-1W	29	869	290
STA-2	90	1366	200
STA-3/4	0	0	0
STA-5	13	311	74
STA-6	1001	4252	687
Total	**1,499**	**8,774**	**1,764**

6. Regional Simulation Modeling

In an effort to determine the possible impacts of the Adaptive Protocol strategy, a hydrologic simulation exercise was performed using the South Florida Water Management Model (SFWMM) (SFWMD, 1999). Additional information about this model is provided at http://www.sfwmd.gov/org/pld/hsm/models/sfwmm/index.html. Due to the fact that releases under Adaptive Protocols are inherently dependent on many changing factors that may not be completely captured during the course of model simulations, the following information should only be used to assess the order of magnitude of potential impacts to agricultural and urban water supply.

6a. Modeling Assumptions

The modeling strategy was designed to compare a base condition that is very similar to the 95BSRR scenario used for the development of the Lower East Coast Water Supply Plan (SFWMD, 2000a) to several alternatives representing operational changes associated with Adaptive Protocols. For all scenarios, climatic data for the 31-year period covering 1965-1995 was analyzed. The key assumptions in the base condition (referred to as 95NEW) are:

- WSE Schedule for Lake Okeechobee
- 1995 wellfield demands as simulated in the LEC Regional Water Supply Plan
- Revised Supply-Side Management with a "trigger line" at 13 ft. NGVD on October 1, sloping down to 10.5 ft. on June 1
- All Lake Okeechobee Service Areas, including the Brighton and Big Cypress Seminole Tribal lands, will be subject to cutbacks as determined by the Supply-Side Management policies
- No forward pumping

Three alternatives were modeled for comparison to 95NEW. The first, denoted as 95N50, incorporated all of the base assumptions of 95NEW as well as a minimum delivery of 50% to the Lake Okeechobee Service Area (LOSA) during periods of Supply-Side Management (SSM) cutbacks for Lake Okeechobee. This scenario is consistent with the approach taken in allocating water during the 2000-2001 drought and provides a better frame of reference than does 95NEW for determining the level of impact of adaptive protocol releases on agricultural water supply. Simulation 95NEW uses a minimum delivery of 33% to LOSA during periods of SSM cutbacks for Lake Okeechobee as was assumed in the LECRWSP (SFWMD, 2000a).

The final two alternatives, 3N50 and 6N50, include environmental supplemental releases from Lake Okeechobee to the Caloosahatchee Estuary, as a proposed adaptive protocol strategy. These two scenarios incorporate all of the assumptions of 95N50 as well as additional Lake Okeechobee demand applied at S-79 to meet environmental needs of the Caloosahatchee Estuary. The magnitude of this demand is 300 cfs for the scenario referred to as 3N50 and 600 cfs for the scenario referred to as 6N50. The intent of these scenarios is to investigate the impact to water supply if releases are made from Lake Okeechobee to meet environmental demand in the Caloosahatchee Estuary when Lake stages are in Zone D of the WSE schedule or higher. It is important to note that demand at S-79 does not translate into supplemental demand entirely on Lake Okeechobee, but rather is first met by runoff from the C43 basin. Only the portion of demand not met by C43 basin runoff becomes a demand on Lake Okeechobee and then is subject to conveyance and operational constraints prior to being delivered. For example, the Lake must be in Zone D or higher of WSE to make releases to the Estuary. As an extra protection to water supply, in the event that conditions at the onset of a dry season indicate a very dry ambient condition or predict a drier than normal condition for that season, the simulated supplemental discharges to the estuary were discontinued during that dry season. This criteria done by using the Palmer Drought Severity Index (PDSI) and a surrogate to La Nina conditions in the Pacific Ocean, which is known to have a reasonable correlation to rainfall during the dry season in Florida. Specifically, when, for any year in the 1965-1995 period of simulation, the PDSI on October 1st for Climate Division 4 (Lake tributary basins) was below -2.5 or the NINO3 index in the Pacific Ocean on October 1st was below -0.6, the estuary demands at S-79 were made equal to zero for the dry season starting on that particular calendar year. For simplicity, only the releases to the Caloosahatchee Estuary were simulated in the 3N50 and 6N50 alternatives. However, it is assumed that these releases represent, at least in the 6N50 scenario, the total quantity that might be released under Adaptive Protocols to all areas of the South Florida regional system. Consequently, the modeling results reported here should provide sufficient information to determine possible impacts to water supply due to the implementation of the Adaptive Protocol strategy.

6b. Modeling Results

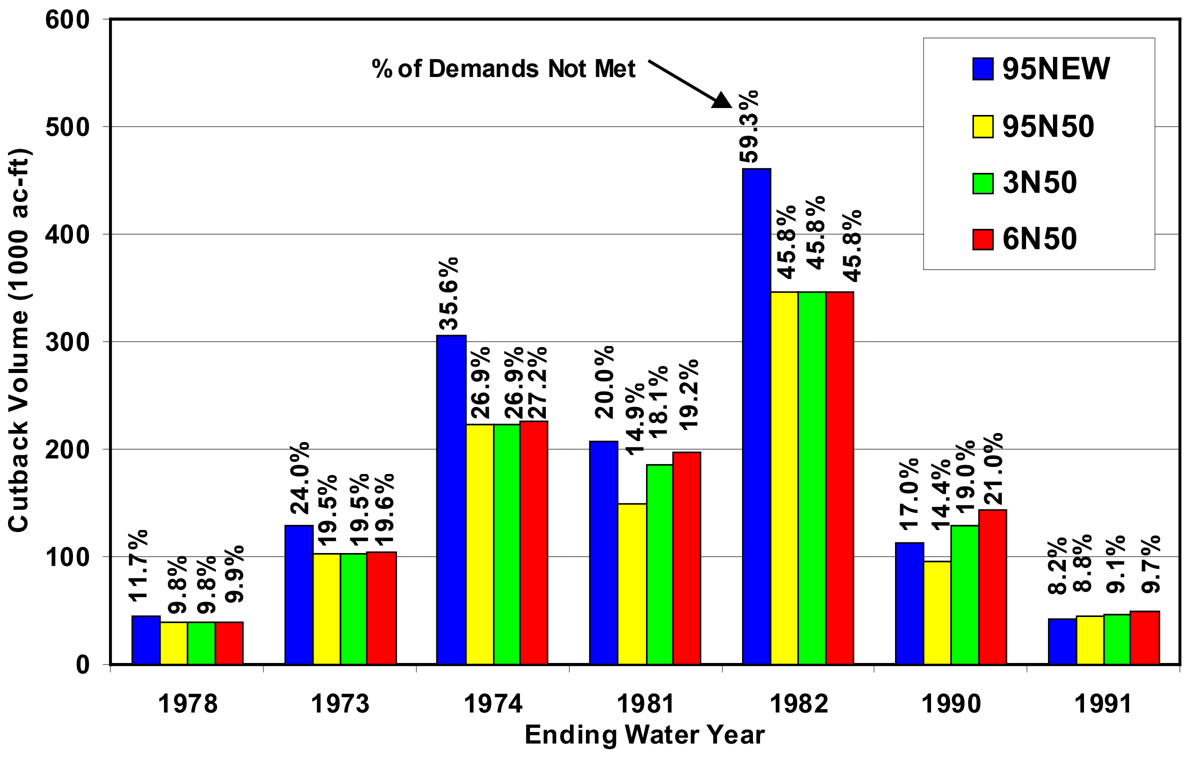
Lake Okeechobee Service Area (LOSA)

The service area of the Lake for water supply includes the Everglades Agricultural Area (EAA), Caloosahatchee Basin, St. Lucie Basin, and numerous smaller basins primarily located in the northern half of the Lake perimeter. These basins depend on the Lake as the primary source of water for agriculture and other uses. When the water levels in the Lake are too low during dry periods, the current management policy calls for cutbacks in water supply. Such cutbacks are based on the SFWMD Supply-Side Management Policy (Hall, 1991), which is the primary tool for managing water supply releases from the Lake during extremely dry periods. Historically, users of Lake Okeechobee water have been and still are concerned about any water management action that may result in low Lake levels and increased cutback volumes. Water Shortage Cutback statistics for Lake Service Area basins for all years as simulated by SFWMM are presented in **Table 14**. Additionally, the LOSA performance during the seven worst years of water supply cutbacks for the SFWMM period of simulation is shown in **Figure 12**.

Table 14. Statistics of water shortage cutbacks for Lake Okeechobee Service Area basins

Performance Measure	95NEW	95N50	3N50	6N50
% Demand Not Met				
(a) EAA	7.8	6.2	6.7	7.1
(b) Caloosahatchee Basin	6.4	5.2	5.8	6.2
(c) St. Lucie Basin	8.3	6.4	7.2	7.7
(d) Other	13.9	12.9	13.1	13.4
Total number of months of water shortages	**35**	**35**	**37**	**38**
Total Supply-Side Management Cutback Volumes (1000 ac-ft over the entire period of 31-year simulation)	**1,314**	**1,009**	**1,114**	**1,187**

Figure 12. LOSA Performance for the seven worst water years (October-September) of water supply cutbacks for the SFWMM period of simulation (1965-1995).



600
500
400
300
200
100
0
Cutback Volume (1000 ac-ft)
% of Demands Not Met
95NEW
95N50
3N50
6N50
11.7%
9.8%
9.8%
9.9%
24.0%
19.5%
19.5%
19.6%
35.6%
26.9%
26.9%
27.2%
20.0%
14.9%
18.1%
19.2%
59.3%
45.8%
45.8%
45.8%
17.0%
14.4%
19.0%
21.0%
8.2%
8.8%
9.1%
9.7%
1978
1973
1974
1981
1982
1990
1991
Ending Water Year

Lower East Coast Service Areas (LECSAs)

The Lower East Coast Service Areas (LECSAs) are located in an urban region at the southeastern tip of the Florida peninsula. With a population of over five million, the main source of water for LECSAs is a surficial aquifer (primarily the Biscayne aquifer). The aquifer is primarily recharged by local rainfall via drainage into a complex network of canals. The maintenance of minimum pre-established water levels in these canals is crucial in preventing saltwater intrusion that could threaten the quality of the water withdrawn from the surficial aquifer. During dry periods, the urban service areas receive water from the Water Conservation Areas (WCAs). When water is not available in the WCAs, i.e. their water levels are below their "floor" elevations, additional supplies are imported from Lake Okeechobee to maintain the canals. Because of this dependence, it is important to ensure that deliveries from Lake Okeechobee to the urban area are maintained under different operational scenarios. This situation will improve as additional sources of water from CERP projects are implemented to replace any potential losses due to changes in the regional system.

The comparison of the base simulation against the three scenarios simulated using the SFWMM is shown in **Table 15**. The frequency (number of months) and percentage of simulated water supply cutbacks in the Lower East Coast Service Areas are shown in **Figures 13** and **14**, respectively. (Note: Service Area 1 in Table 9 is broken down into LECSA1 and LECSA Northern Palm Beach County in these two Figures).

6c. Modeling Conclusions

It is recognized that large releases of water from Lake Okeechobee (e.g. to meet environmental demands in Caloosahatchee Estuary) may have potential impacts on water supply in the Lake Okeechobee and Lower East Coast Service Areas, particularly during droughts. However, regional modeling simulations indicate that the effect of the simulated adaptive releases (0 - 600 cfs) on existing water supply needs is minimal. A limited set of modeling scenarios was investigated as discussed in the previous section. A more detailed discussion of these simulations and additional performance measures can be found at http://www.sfwmd.gov/org/pld/hsm/reg_app/opln/ADP/index.html.

Actual releases under Adaptive Protocols will be made on a case-by-case basis with due consideration of checks and balances as discussed in Section 4. Future opportunities via additional modeling and/or evaluation of conditions prior to adaptive releases within the scope of the WSE schedule will be explored as they impact water supply in LOSA and LECSAs.

Table 15. Regional Water Supply to Three Major LEC Service Areas for the October-to-May Period (all volumes are in units of 1,000 ac-ft)

Service Area 1 (primarily Palm Beach County)

Condition	From LOK				From WCA				TOTAL			
	95NEW	95N50	3N50	6N50	95NEW	95N50	3N50	6N50	95NEW	95N50	3N50	6N50
Dry	14.6	14.6	14.8	14.6	11.3	11.3	11.1	11.1	26.0	25.9	25.9	25.7
Net		0.0	0.1	0.0		-0.1	-0.2	-0.3		-0.1	-0.1	-0.3
%Change		0%	1%	0%		-1%	-2%	-2%		-0.3%	-0.3%	-1.1%
Average	35.2	35.2	33.9	33.3	23.6	23.5	24.2	24.3	58.8	58.7	58.1	57.6
Net		0.0	-1.2	-1.8		-0.1	0.6	0.7		-0.1	-0.7	-1.2
%Change		0%	-4%	-5%		-1%	2%	3%		-0.2%	-1.1%	-2.0%
Wet	57.0	57.0	56.5	55.8	63.6	63.6	63.5	63.5	120.6	120.5	120.0	119.3
Net		0.0	-0.5	-1.2		-0.1	-0.1	-0.1		-0.1	-0.6	-1.2
%Change		0%	-1%	-2%		0%	0%	0%		0.0%	-0.5%	-1.0%

Service Area 2 (primarily Broward County)

Condition	From LOK				From WCA				TOTAL			
	95NEW	95N50	3N50	6N50	95NEW	95N50	3N50	6N50	95NEW	95N50	3N50	6N50
Dry	0.0	0.0	0.0	0.0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Net		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0
%Change						0%	0%	0%		0.0%	0.1%	0.2%
Average	0.6	0.5	0.5	0.4	4.8	4.8	4.7	4.7	5.3	5.2	5.2	5.1
Net		-0.1	0.0	-0.1		0.0	-0.1	-0.1		-0.1	-0.1	-0.2
%Change		-16%	-8%	-20%		0%	-2%	-1%		-1.6%	-2.2%	-3.2%
Wet	8.7	8.8	8.9	8.7	11.5	11.4	11.4	11.4	20.2	20.1	20.2	20.0
Net		0.1	0.2	0.0		-0.1	-0.1	-0.1		0.0	0.1	-0.1
%Change		1%	2%	0%		-1%	-1%	-1%		-0.2%	0.3%	-0.6%

Service Area 3 (primarily Miami-Dade County)

Condition	From LOK				From WCA				TOTAL			
	95NEW	95N50	3N50	6N50	95NEW	95N50	3N50	6N50	95NEW	95N50	3N50	6N50
Dry	0.0	0.0	0.0	0.0	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7
Net		0.0	0.0	0.0		-0.1	0.0	-0.1		-0.1	0.0	-0.1
%Change						0%	0%	0%		-0.2%	-0.1%	-0.2%
Average	4.4	4.4	4.5	4.4	87.4	87.4	87.4	87.6	91.8	91.8	91.9	91.9
Net		0.0	0.0	-0.1		0.0	0.0	0.2		0.0	0.1	0.1
%Change		0%	1%	-2%		0%	0%	0%		0.0%	0.1%	0.1%
Wet	58.4	57.4	57.5	57.3	131.8	131.7	131.5	131.2	190.2	189.1	189.0	188.6
Net		-1.0	-0.9	-1.1		-0.1	-0.3	-0.6		-1.2	-1.2	-1.7
%Change		-2%	-2%	-2%		0%	0%	0%		-0.6%	-0.7%	-0.9%

Figure 13. Number of Months of Simulated Water Supply Cutbacks for the 1965-1995 Simulation Period in the Lower East Coast Service Areas.

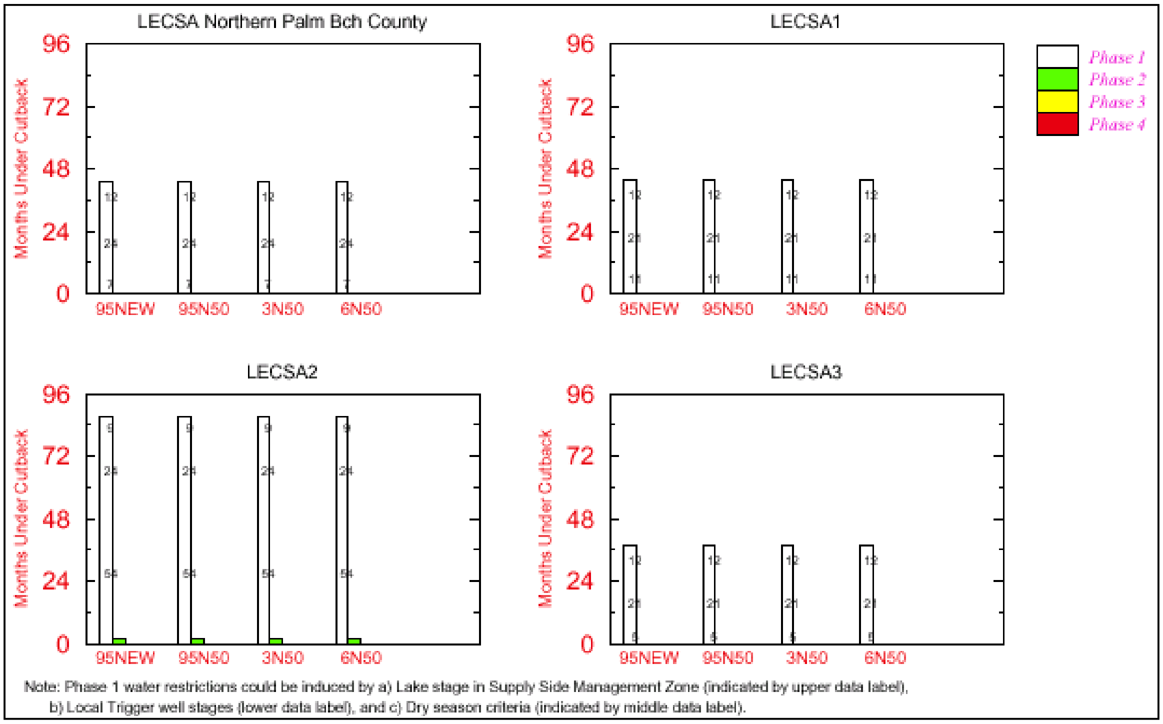
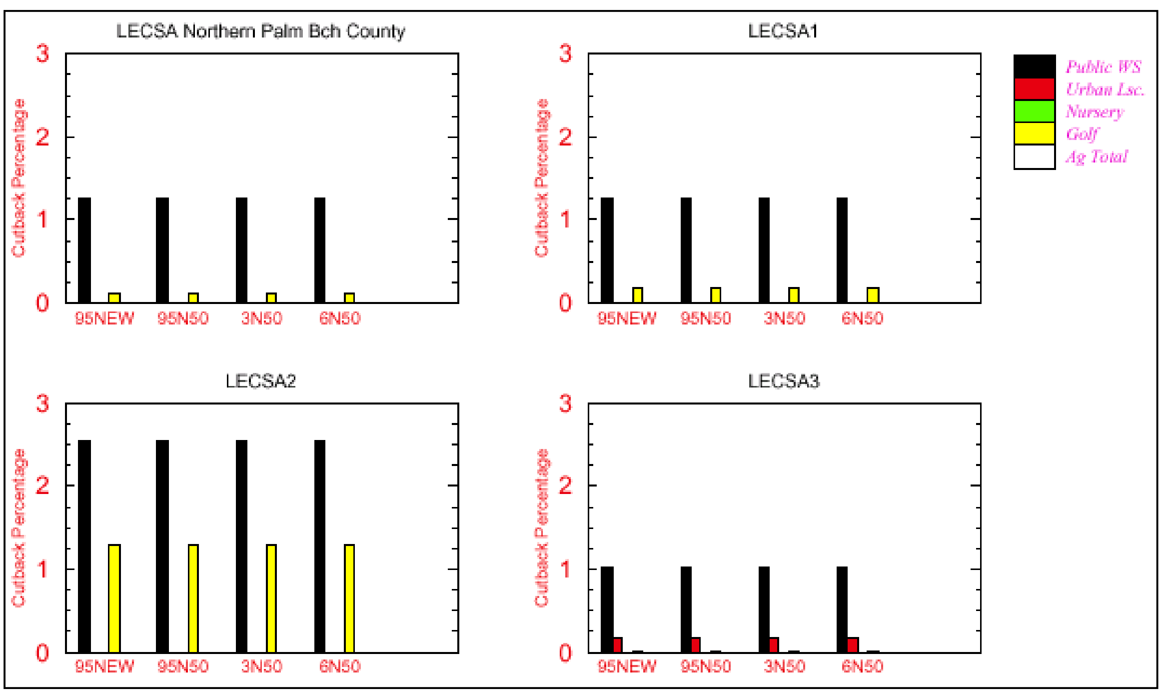


Figure 14. Percentage of Simulated Water Supply Cutbacks by Use-Type for the 1965-1995 Simulation Period in the Lower East Coast Service Areas.



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Appendix I

Information regarding the Palmer Index used to calculate drought conditions

The Palmer Drought Severity Index (PDSI) is a meteorological drought index and responds to weather conditions that have been abnormally dry or abnormally wet. When conditions change from dry to normal or wet, for example, the drought measured by the PDSI ends without taking into account stream flow, lake and reservoir levels, and other longer-term hydrologic impacts. The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil. From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer. Human impacts on the water balance, such as irrigation, are not considered. Complete descriptions of the equations can be found in the original study by Palmer (1965) and in the more recent analysis by Alley (1984).

Palmer developed the PDSI to include the duration of a drought (or wet spell). His premise was as follows: an abnormally wet month in the middle of a long-term drought should not have a major impact on the index, and a series of months with near-normal precipitation following a serious drought does not mean that the drought is over. Therefore, Palmer developed criteria for determining when a drought or a wet spell begins and ends, which adjust the PDSI accordingly. Palmer (1965) described this effort and gave examples, and it is also described in detail by Alley (1984).

<u>PDSI values for the 11 drought (or wet) categories</u>:

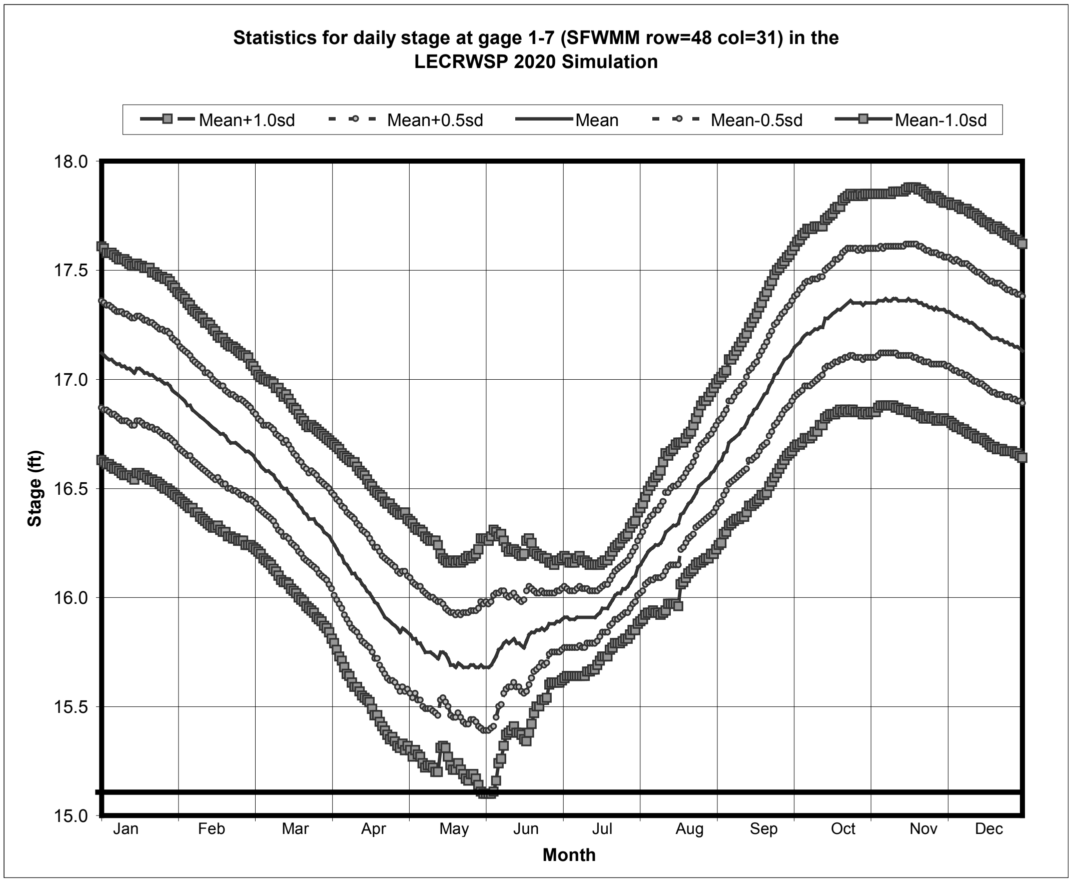
4.0 and above	Extreme moist spell
3.0 to 3.99	Very moist spell
2.0 to 2.99	Moist spell
1.0 to 1.99	Moist spell
0.50 to 0. 99	Incipient moist spell
0.49 to -0.49	Near normal
-0.50 to -0.99	Incipient dry
-1.0 to -1.99	Drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 and below	Extreme drought

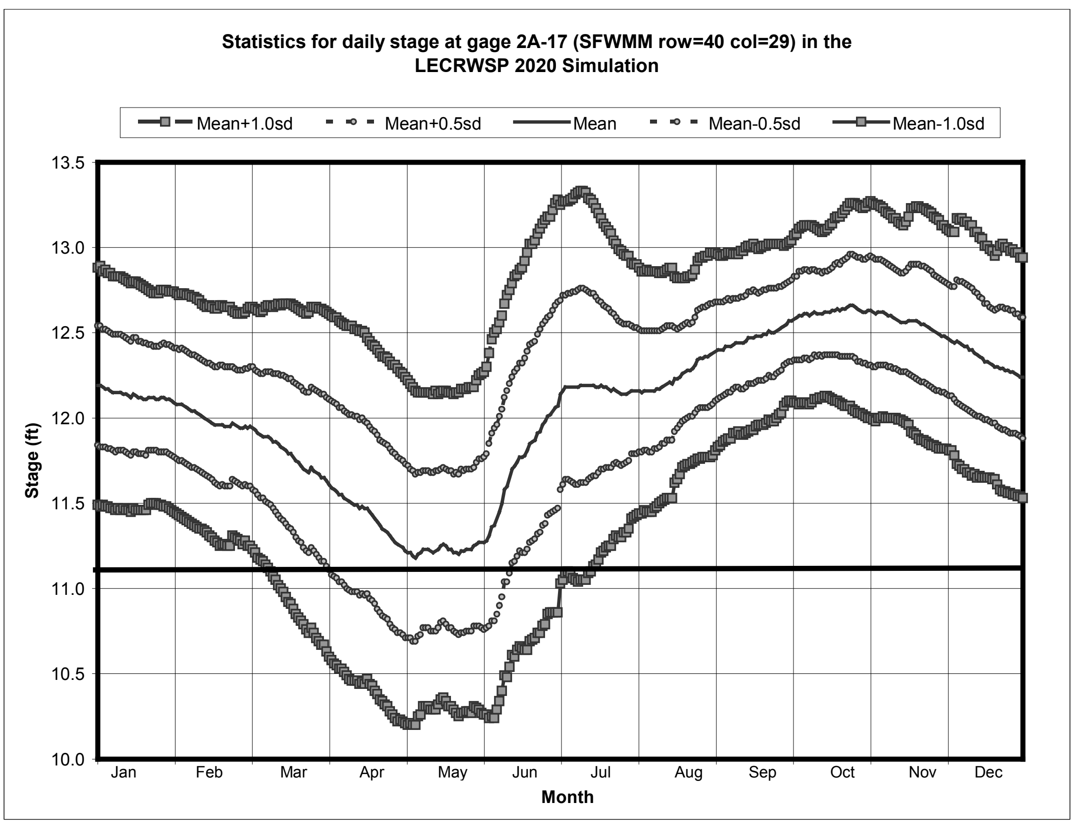
Appendix II

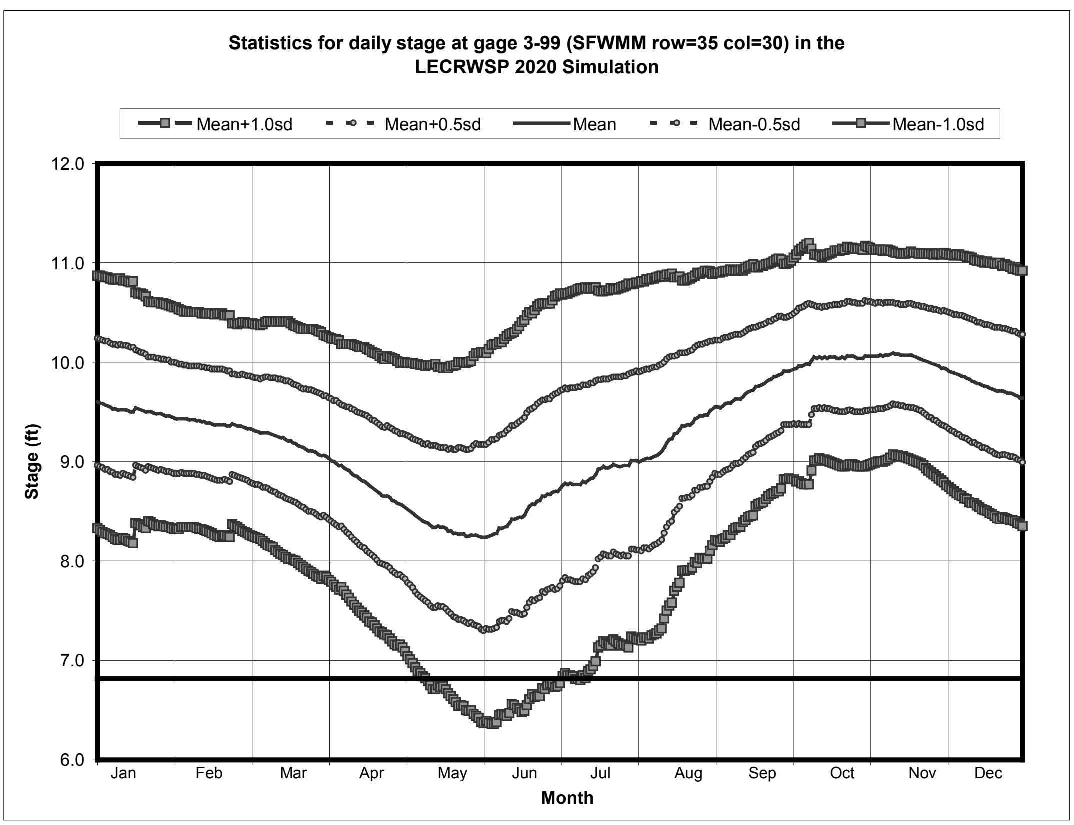
Restoration Targets and Minimum Flows and Levels for the Everglades Protection Area

Figure II-1. Seasonal hydrographs at gauges in the Everglades Protection Area, based on LEC2020 restoration targets (in the following 10 successive panels).

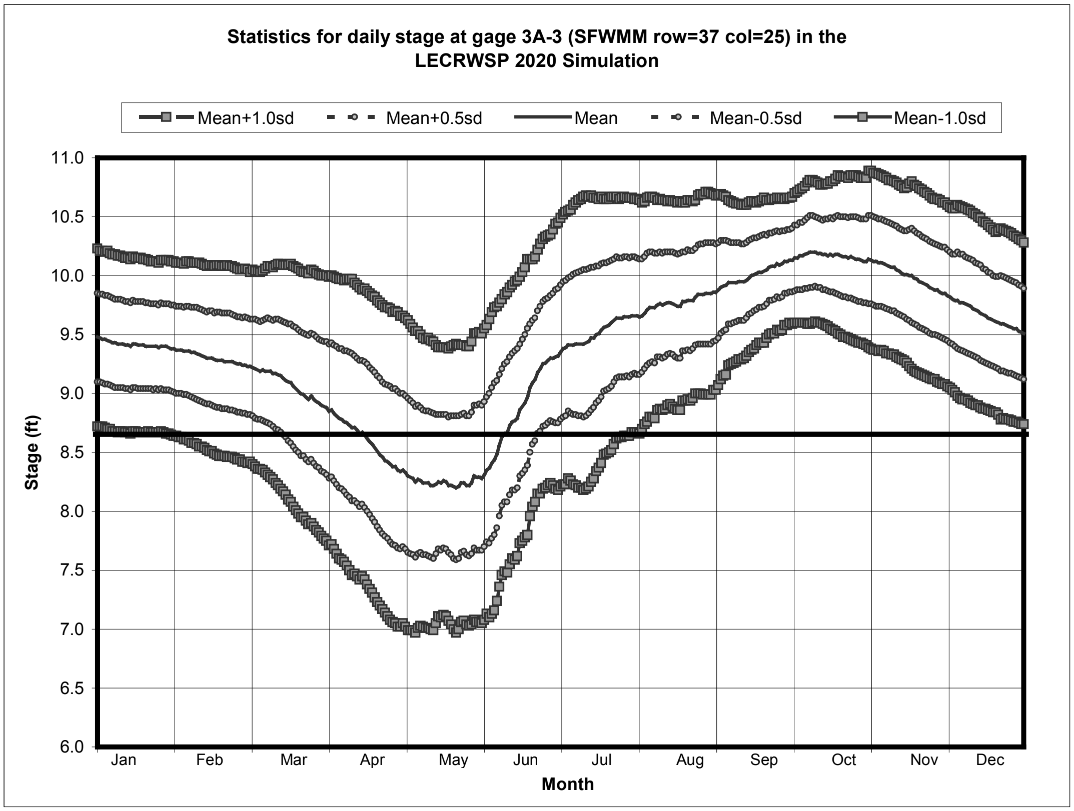
The **bold** horizontal line on each graph indicates floor elevation.

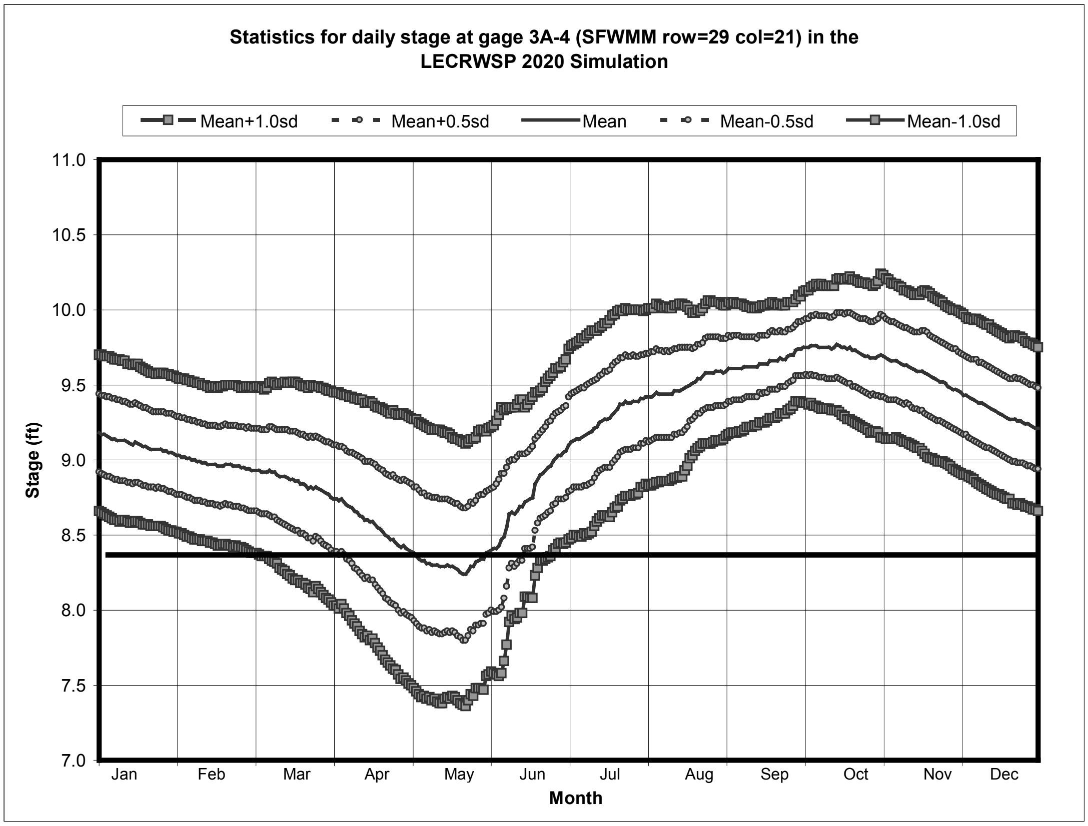

Statistics for daily stage at gage 1-7 (SFWMM row=48 col=31) in the LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
18.0
17.5
17.0
16.5
16.0
15.5
15.0
Stage (ft)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

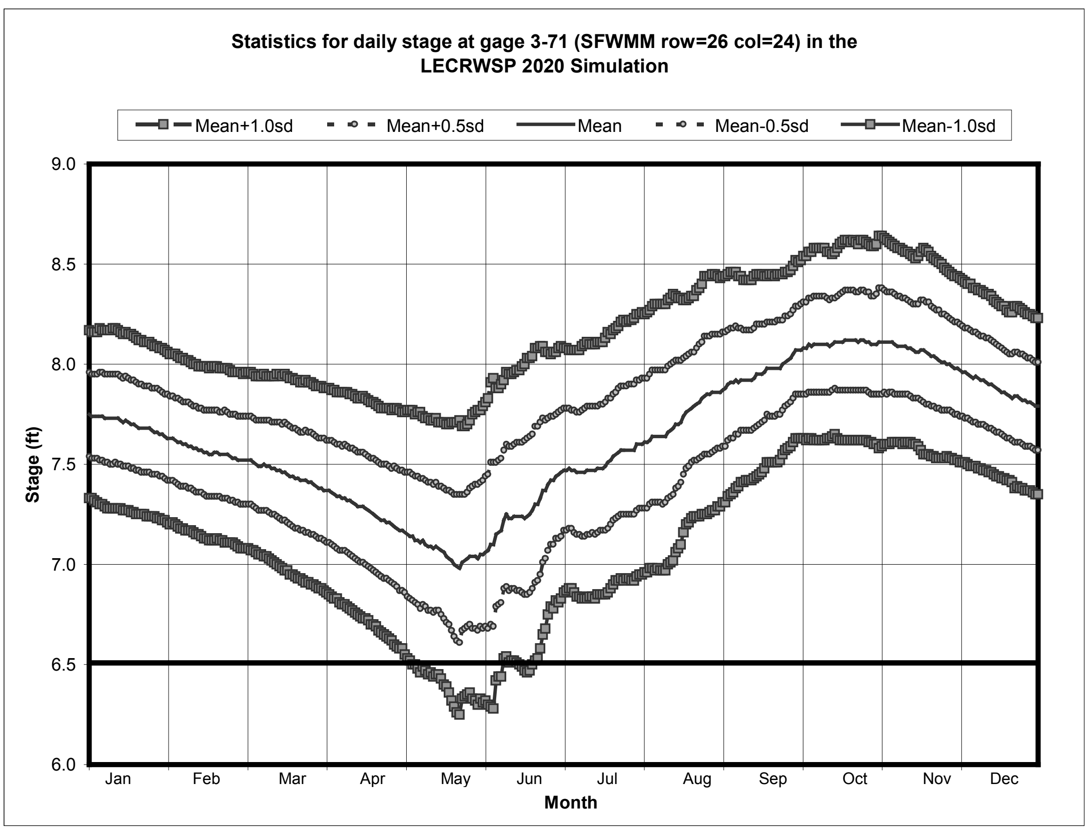

Statistics for daily stage at gage 2A-17 (SFWMM row=40 col=29) in the LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
Stage (ft)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

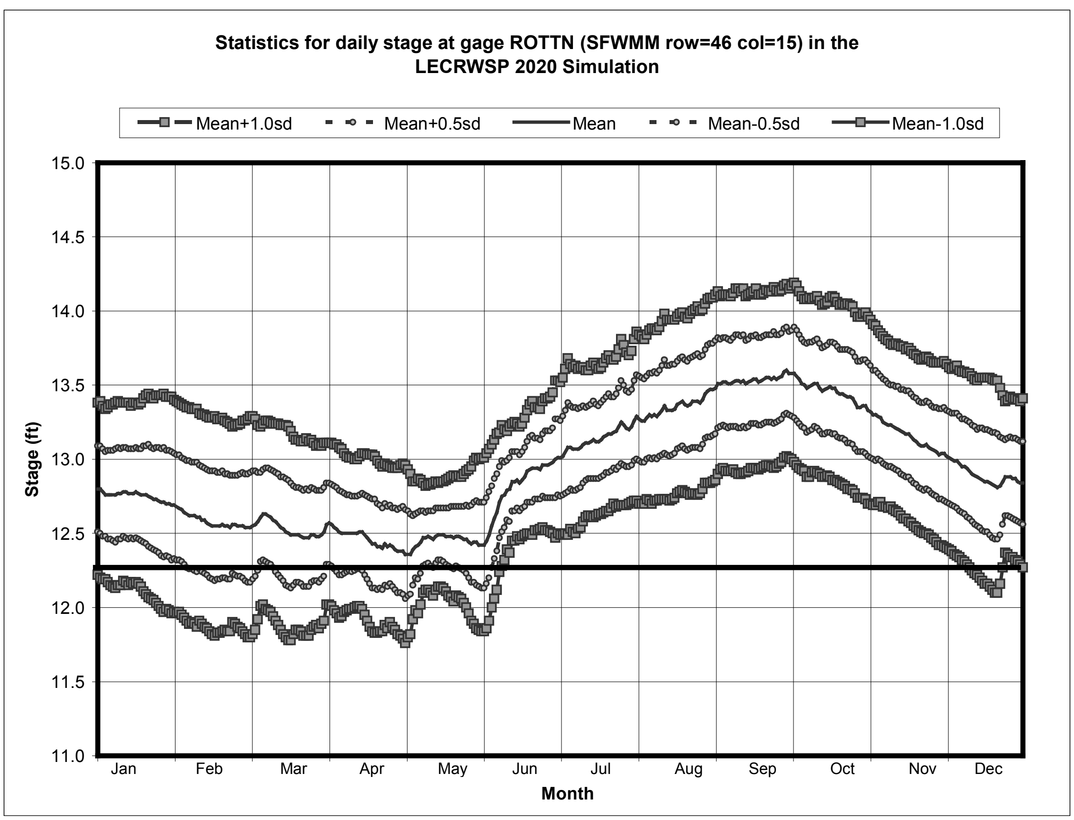


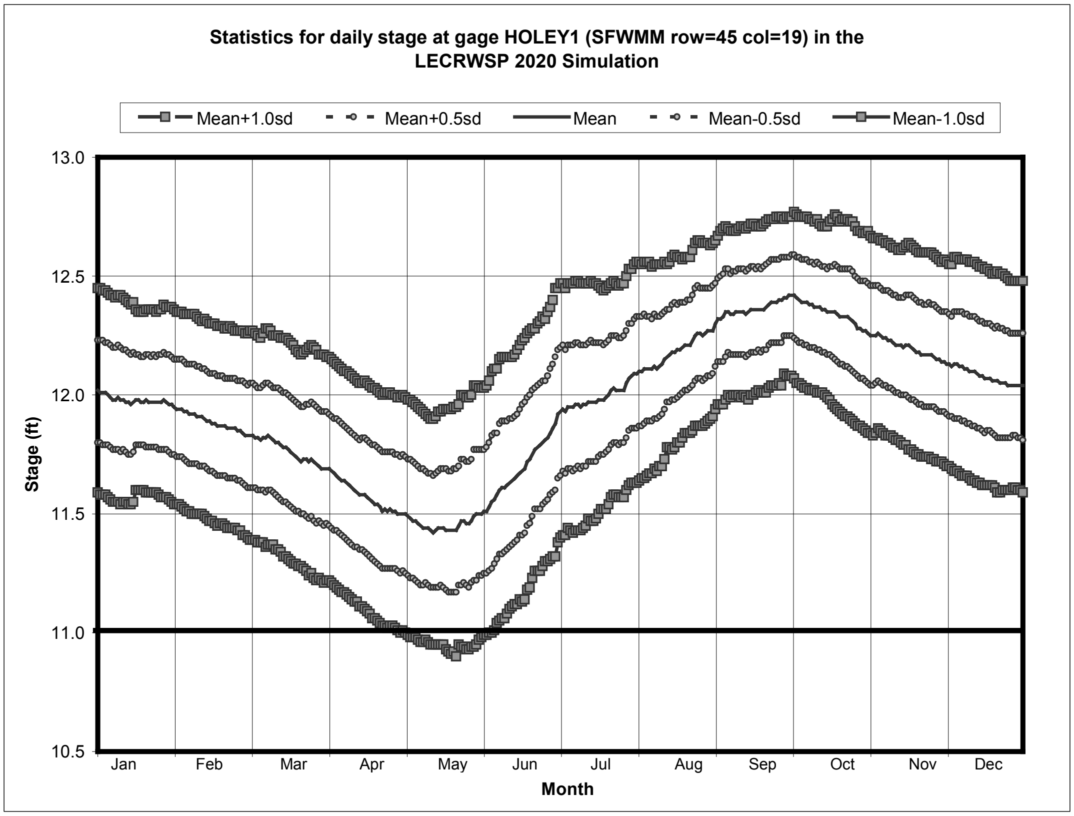
Statistics for daily stage at gage 3-99 (SFWMM row=35 col=30) in the
LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
12.0
11.0
10.0
9.0
8.0
7.0
6.0
Stage (ft)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

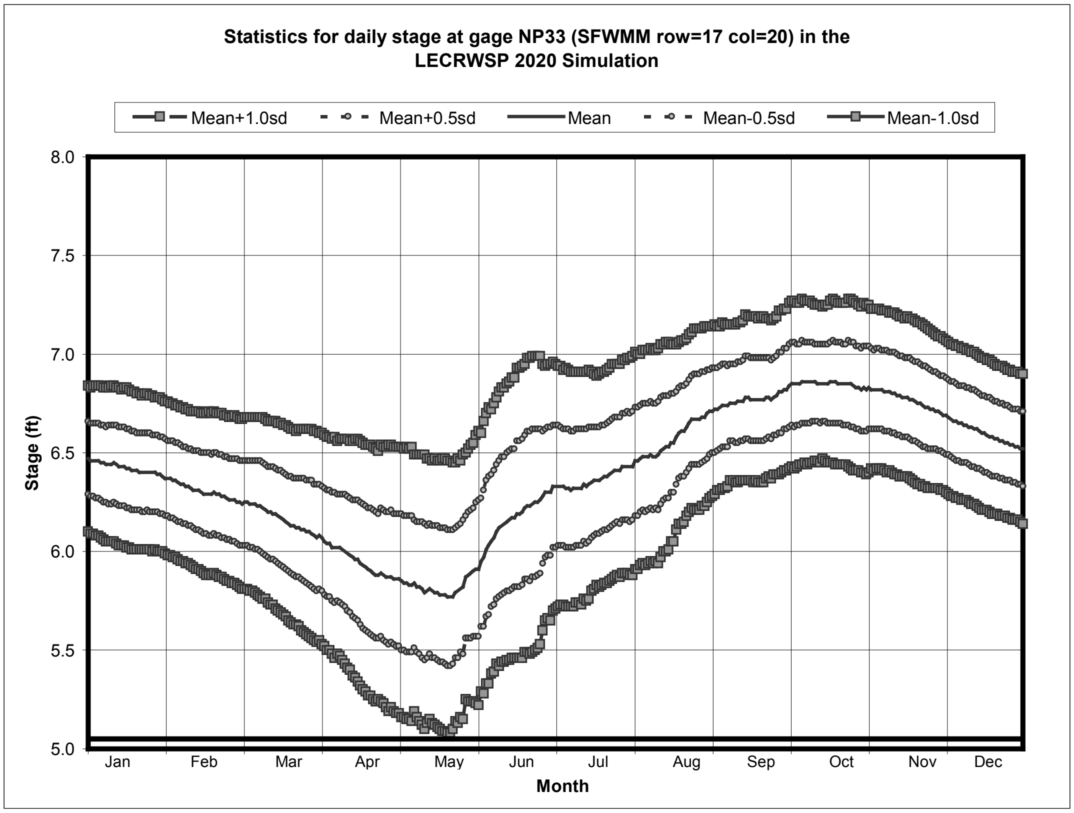

Statistics for daily stage at gage 3A-3 (SFWMM row=37 col=25) in the
LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

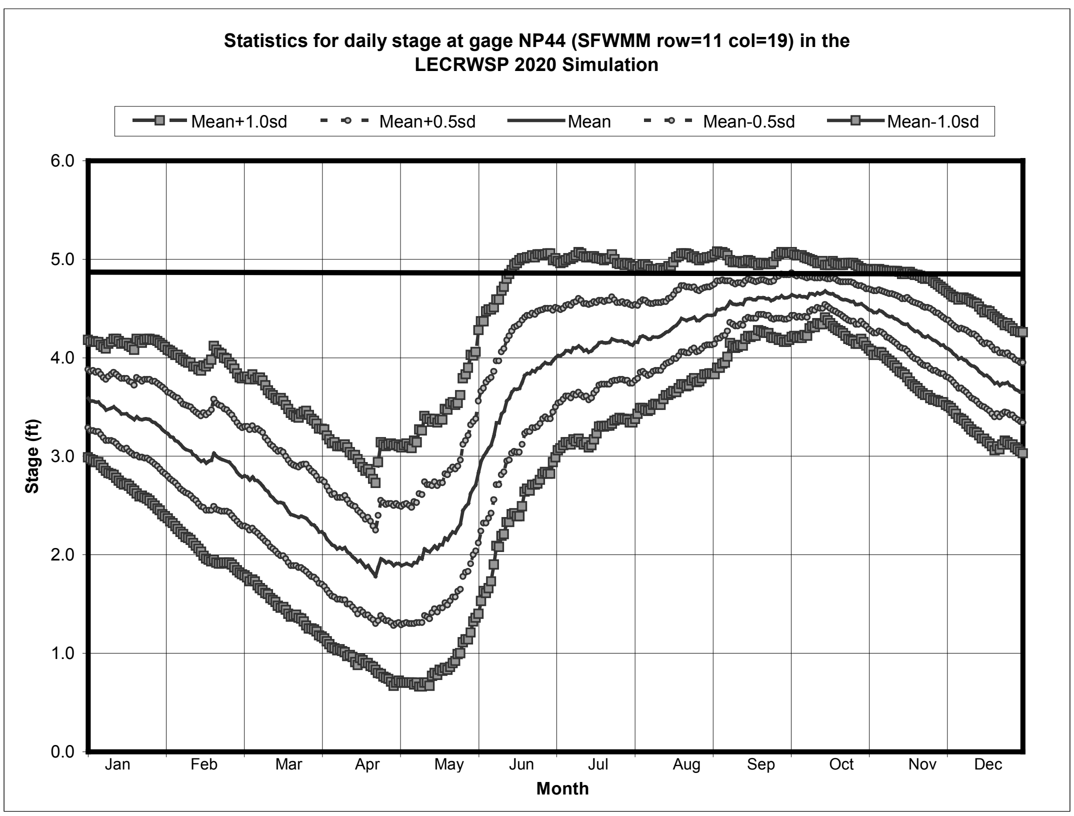

Statistics for daily stage at gage 3A-4 (SFWMM row=29 col=21) in the
LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Statistics for daily stage at gage 3-71 (SFWMM row=26 col=24) in the
LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Statistics for daily stage at gage ROTTN (SFWMM row=46 col=15) in the
LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Statistics for daily stage at gage HOLEY1 (SFWMM row=45 col=19) in the LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
13.0
12.5
12.0
11.5
11.0
10.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Statistics for daily stage at gage NP33 (SFWMM row=17 col=20) in the LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Statistics for daily stage at gage NP44 (SFWMM row=11 col=19) in the LECRWSP 2020 Simulation
Mean+1.0sd
Mean+0.5sd
Mean
Mean-0.5sd
Mean-1.0sd
Stage (ft)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Appendix II (Continued)

Table II-1. Minimum water levels, duration and return frequencies for key water management gauges located within the Everglades (1,2, 3)

Area	Key Gauge	Soil Type & MFL Criteria	Return Frequency (years) (3-4)
WCA-1	1-7	Peat(1)	1 in 4
WCA-2A	2A-17	Peat	1 in 4
WCA-2B	2B-21	Peat	1 in 3
WCA-3A North	3A-NE	Peat	1 in 2
WCA-3A North	3A-NW	Peat	1 in 4
WCA-3A North	3A-2	Peat	1 in 4
WCA-3A North	3A-3	Peat	1 in 3
WCA-3A Central	3A-4	Peat	1 in 4
WCA-3A South	3A-28	Peat	1 in 4
WCA-3B	3B-SE	Peat	1 in 7
Rotenberger WMA	Rotts	Peat	1 in 2
Holeyland WMA	HoleyG	Peat	1 in 3
NE Shark Slough	NESRS-2	Peat	1 in 10
Central Shark Slough	NP-33	Peat	1 in 10
Central Shark Slough	NP 36	Peat	1 in 7
Marl wetlands east of Shark Slough	NP-38	Marl (2)	1 in 3
Marl wetlands west of Shark Slough	NP-201 G-620	Marl	1 in 5
Rockland marl marsh	G-1502	Marl	1 in 2
Taylor Slough	NP-67	Marl	1 in 2

(1) = MFL Criteria for Peat-forming wetlands: Water levels within wetlands overlying organic peat soils within the water conservation areas, Rotenberger and Holey Land wildlife management areas, and Shark River Slough (Everglades National Park) shall not fall 1.0 feet or more below ground surface, as measured at a key gauge, for one or more days during a period in which the water level has remained below ground for at least 30 days, at specific return frequencies shown above.

(2) = MFL Criteria for Marl-forming wetlands: Water levels within marl-forming wetlands that are located east and west of Shark River Slough, the Rocky Glades, and Taylor Slough within the Everglades National Park, shall not fall 1.5 ft. below ground surface, as measured at a key gauge, for one or more days during a period in which the water level has remained below ground for at least 90 days, at specific return frequencies for different areas, as shown above.

(3) = Return frequencies were developed using version 3.7 of the South Florida Water Management Model (SFWMM) and are the same as those stated on page 168, Table 44 of the adopted LEC Regional Water Supply Plan (May 2000).

(4) = MFL depth, duration and return frequencies are based on historic rainfall conditions for the 31-year period of record from 1965 to 1995.

Appendix II (Continued)

Figure II-2. Location of MFL monitoring gauges in relationship to major hydric soil types within the Everglades Protection Area.